ANNUAL REPORT 1967–68

Division of Meteorological Physics

Commonwealth Scientific and Industrial

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CONTENTS

DIVISION OF METEOROLOGICAL PHYSICS

ANNUAL REPORT

1967 - 1968

I INTRODUCTION

The Division's two principal objectives are a better understanding of the fundamental processes of meteorology and the application of this knowledge to problems of economic importance to Australia. For example, whilst in dynamic meteorology the main effort is devoted to basic problems of atmospheric mechanics, more empirical studies of practical value, such as the effect of irrigation and rolling on nocturnal temperatures in vineyards also receive attention. More directly related to immediate needs is the work in agriculture and the efficient use of water by plants. It is in such contexts as these that many of the results and techniques which derive from 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) Numerical Modelling. Further collaboration with the Geophysical Fluid Dynamics Laboratory, Washington, D.C., using the 9-level mathematical model devised there, has resulted in experimental southern hemisphere prediction tests extending over periods of 14 days. Although analyses are not yet completed, the preliminary results are most encouraging. For example, in one period in the southern hemisphere the correlation coefficients between predicted and observed height changes at the 500 mb level, from one to 14 days ahead, averaged 0.6; but if comparisons are restricted to the Australasian region the coefficient rises to 0.8. In view of the data limitations of the southern hemisphere, these figures represent a surprisingly high performance. If further experiments prove them to be representative,

useful forecasts for the hemisphere, and improved ones for Southern Australia, will be assured when the numerical techniques can be incorporated into operational routines.

(b) The Boundary Layer. Dimensional analysis shows that under certain restrictive assumptions, boundary layer turbulence characteristics can be expressed as universal functions of non-dimensional height and stability.

Non-dimensional profiles of temperature, wind shear, stress, dissipation, eddy viscosity and mixing length have been determined for a variety of stabilities, and the stability-dependent parameters linking flow and temperature in the free atmosphere to stress and heat flux at the surface have also been deduced. The extent to which these relationships can be considered as generally valid has yet to be finally determined. The results of the "Wangara" expedition to Hay, New South Wales, mounted by this Division, in collaboration with the Bureau of Meteorology in July-August, 1967, are in the course of being evaluated. The object of this work is, from specifications of the radiative fluxes, temperature, humidity and wind at the top of the boundary layer, and the nature of the surface, to compute stress and heat and moisture flux at the ground together with velocity, temperature and moisture content throughout the boundary layer for any geographical location. Such information is essential to the construction of proper mathematical models of the atmosphere.

(c) Momentum, heat and water vapour flux in and above the boundary layer. A transition in the scale of turbulence producing vertical fluxes is known to occur in the lower layers of the atmosphere, but the scales operative at the higher levels are inadequately known. It is expected that the observations taken on the Wangara expedition will provide valuable information on these matters. Measurement of fluxes both at the surface and higher levels on the scales of about 80 km and one hour (three hours for heat and moisture) were successfully achieved over a period of 40 days. Although only preliminary results are as yet available, the figures

tend to confirm that fluxes on this scale are important in the global momentum balance and that relatively large fluxes occur in the vicinity of the meridional fronts which are such a striking feature of the west wind belts. The role of unsteadiness in the production of these fluxes is being examined.

(d) Oscillations in the Stratosphere. Further analyses of up to 30 years' observations of total ozone, temperature and wind have revealed a quasi-biennial oscillation in the stratosphere extending from the northern tropics to Antarctica. Data from the Krakatoa volcanic eruption in 1883 as well as stratospheric wind measurements made at the turn of the century have also been incorporated in the investigation. Results show that breaks in the oscillation are related to the solar cycle, the observed reduction in amplitude and shift of phase preceding sunspot minima.

Sunspot activity has also been shown to have a bearing on the 26-month period of the major equatorial oscillation, which so far has defied explanation. It can be accounted for on the hypothesis of sub-harmonic response to semi-annual forcing in the equatorial zone and angular modulation by the 22-year double sunspot cycle. This argument may also be invoked to explain the 13-month wind cycles in the equatorial stratosphere in terms of an annual wave modulated by the 11-year solar cycle.

Biennial-mode responses in the stratosphere are the subject of studies currently being carried out in various countries, the mechanisms of vertical and horizontal coupling presenting a major problem. The detailed investigation of meridional eddy-transport of momentum and heat in the atmosphere over Antarctica has been extended to 10 years' data and a similar study commenced employing Australian data.

It has been found that biennial cycles in temperature, wind and the other transports mentioned are superimposed on long-term trends in these quantities. The trends are consistent with a response of the stratospheric circulation to solar activity which has been detected in other data, in

particular the Arosa ozone observations which extend over a period of 30 years.

(e) The Southern Oscillation. Work on the mechanism of the Southern Oscillation, mentioned in previous reports, has continued. Regressions of pressure on Walker's Southern Oscillation Index and statistical relations between surface and geostrophic wind have been used to determine the variation of surface divergence anomaly, with Oscillation Index. Taking a standard deviation of the Index of +1, it was found that during the winter at a latitude of 20^{o} south, there existed a positive divergence anomaly over the central and east Pacific and a negative one over the Australian-Indian Ocean area. The order of magnitude was 10^{-7} sec^{-1}. However, the principal contribution to the anomaly arises from the divergence (with latitude) of the meridional wind components - indicating that the simple concept of an east-west circulation in a zonal plane is inadequate.

In near steady conditions, the mean divergence anomaly at upper levels is equal in magnitude but opposite in sign to that at the surface, so that, vertically integrated, they balance out. Such an anomaly can be considered as being made up of a number of terms, some depending on long term averages, some on monthly anomalies and others on daily departures from the mean. Consideration has been given to divergence anomalies as related to zonal ageostrophic flow and estimates made of some of these terms. Aerological data, obtained principally during the winter at 20^{o} south from the 200/500 mb level, were used for the study. Results indicate that the ageostrophic flow associated with ascending or descending air and an east-west temperature gradient is not big enough to be important in the Southern Oscillation mechanism - except possibly that part of the flow associated with daily departures from average.

Radar Meteorology

The Structure of Dry Cold Fronts. The work referred to in last year's annual report on the

anomalous radar reflections known as "angel echoes" has continued. These echoes have the appearance of lines or bands and are associated with shallow, dry cold fronts which approach Aspendale from Port Phillip Bay during the summer. Further observations have been made on extensive echo bands in conjunction with measurements of frontal fine structure of wind, refractive index and temperature. On one occasion a capacitor refractometer recorded the refractive index micro-structure. The frontal zones were found to have varying thicknesses ranging from a few metres to 10's of metres and to be associated with temperature falls amounting to several degrees centigrade. A high correlation - which extended down to the very fine structure - existed between temperature and micro-wave refractive index, a decrease in the former accompanying an increase in the latter, presumably due to a positive correlation between temperature and water vapour pressure.

To explain more fully the frontal mechanism which gives rise to this particular kind of micro-wave refraction in the lower atmosphere, the work needs to be continued for another season. It is necessary to establish, for instance, whether the echoes result from specular reflection produced by extensive refractive index discontinuities or by forward and back scattering from a turbulent layer. With this in mind the 10 cm radar has been instrumented to permit calibration for minimum detectable power, on a routine basis.

III THE UPPER ATMOSPHERE

Ozone

Observations of total ozone and determinations of its vertical distribution by the "umkehr" method have continued at Darwin, Brisbane, Aspendale, Hobart and Macquarie Island in collaboration with the Bureau of Meteorology and the Antarctic Division of the Department of External Affairs. The regular weekly ozone soundings using the Brewer-Mast ozone sondes have continued at Aspendale, and also the daily observations of surface

ozone at Aspendale and Macquarie Island using Ehmert's equipment. Supplementing these were some three months' continuous measurements of surface ozone employing a Brewer-type bubbler developed in the Division.

Further night time measurements of ozone on all the standard wavelength pairs used in the Dobson spectrophotometer have been made at Hay and Hobart and agree well with the findings reported last year. Using the B(λ3088/3291) pair of wavelengths, the night time ozone amount is apparently significantly smaller than the day time value, implying enhanced radiation at 3088A^{o}. The tentative assumption that most of this radiation comes from the Herzberg O_2 band has since been confirmed by comparing radiation calculated from solar intensity and lunar reflectivity with that emitted by the Herzberg band. Within the limits of accuracy of the former computation the agreement was good.

In 1963, a 26-month oscillation in the spring ozone maximum at Aspendale and Brisbane broke down. Now it has reappeared but with reversed phase. A connection between the breakdown and the solar cycle has been suggested. It is proposed that the variation in solar emission associated with the 22-year double sunspot cycle is responsible for the period of the 'biennial' cycle being 26 months. This is dealt with in somewhat greater detail on page 4 under "Oscillations in the stratosphere".

Analysis of seasonal and long term trends in the three years' ozone sonde data so far accumulated has revealed a number of features of the ozone structure and its relationship to circulation processes. In respect of transport systems in the lower stratosphere both transient and standing eddies were found to be important. Analysis of the data with reference to the 300 mb synoptic pattern has shown highly significant differences between mean ozone distribution in ridges and troughs and that obtaining on either side of the middle latitude jet stream. These differences extend from the surface up to as high as 25 mb. The "folding in" of the stratospheric air into the troposphere in the vicinity

of the jet stream is indicated in the mean distributions.

Work is also well advanced on an inter-comparison of individual soundings as well as mean distributions derived from two methods - ozone sonde and "umkehr".

From surface ozone measurements made at Aspendale it has been observed that the daily surface ozone maximum, averages 70-80 $\mu gm/m^3$ in late summer and about 40 $\mu gm/m^3$ in winter.

No significant correlation has been found between surface and total ozone for any time of the year. However, there were appreciable increases in surface ozone to the rear of anti-cyclones in summer and to the rear of troughs in the winter. Also, as opposed to the strong, northward meridional flux of ozone observed in Antarctica, it was found that at Aspendale the meridional flux was weak and southwards between March and October but northwards between November and February.

Preliminary measurements at Hay of the ozone destruction rate at the earth's surface gave an average figure of $0.8 \times 10^{11} mol/cm^2$ sec. It is proposed to expand the work and make similar measurements in a variety of weather situations, for which purpose a modified Ehmert's apparatus is being developed.

Radioactivity, Volcanic Dust and Water Vapour as Atmospheric Tracers

During the past year the main factor influencing the progress of the work in radioactive atmospheric tracers has been the acquisition of a multi-channel γ-ray analyser. Not only can the analyses be performed much more quickly and accurately, but it is now possible to study fission products such as Cs-137, Ce-144 and Zr-95. These elements result from nuclear weapons tests and are primarily of equatorial origin in contrast to Be-7, a naturally occurring isotope produced in the polar stratosphere by the action of cosmic radiation. The

new techniques have provided conclusive evidence that Be-7 holds great promise as a stratospheric tracer and it is hoped that its use in conjunction with others originating in low latitudes will add considerably to our knowledge of the general circulation. The following table gives brief details of the isotopes currently in use:-

Isotope	Emission	Sampling
Be-7 (natural)	γ	Rain at ground level, monthly at Aspendale. Air at 1.5 m, weekly at Aspendale. Stratospheric profiles every 3 months.
Cs-137 (fission product)	γ	
Ce-144 (fission product)	γ	
Zr-95 (fission product)	γ	
S-35 (natural)	β	Air at 1.5 m, weekly at Aspendale.

Concentrations of the first four in air and rain water and S-35 in air alone are measured on a routine basis. The atmospheric profiles are obtained through the good offices of the Department of Supply's balloon launching station at Mildura - project "Hibal".

The Division continues to operate air sampling equipment for the U.K. Atomic Energy Research Establishment at Harwell.

Last year's report referred to a global survey of solar radiation depletion resulting from dust injected into the stratosphere by the 1963 Bali volcanic eruption. The quantity of dust in the air was found to depend on the season: in middle latitudes for example the maximum occurs in mid winter and moves towards the poles undiminished at a rate of about 40 cm sec^{-1}. A study of spherical diffusion has indicated that the observed behaviour cannot be attributed to mixing alone but is probably due to a combination of this plus seasonal-dependent mean motion.

In cooperation with the Division of Radiophysics, stratospheric aerosol layers are being investigated using cameras flown on the Hibal balloons referred to earlier. Clearly defined layers can easily be seen and there appear to be prospects of using these as indicators of mean motion in the stratosphere.

The development of a sensor capable of measuring the extremely low concentrations of water vapour found in the stratosphere is progressing. The concentrations to be measured are so small (of the order 1 ppm) that cleanliness and elimination of the water contained in the molecular structure of the materials forming the sensor are critical.

Experience elsewhere has indicated that measurement of the naturally occurring isotopes Pb-214 and Bi-214 may provide a means of assessing atmospheric stability. These isotopes result from the radioactive decay of radon, itself a product of the small amounts of radium present in the soil. Concentrations of Pb-214 and Bi-214 in surface air are a function of surface wetness and stability but considered as a ratio should depend mainly on stability. A small scale feasibility programme is under way.

IV GENERAL MICROMETEOROLOGY

An extensive series of temperature and humidity records were obtained in the field with a rapid response thermometer and refractometer. Analysis of the data is now well advanced and several results merit comment. For both variables, the characteristic scale of turbulence is dependent on stability: at Richardson numbers (Ri) of about -0.08 the scales are a maximum. Spectral calculations of the fluctuations yielded good agreement with the theory of isotropic turbulence where the spectral estimates are proportional to the wave number (k), with a -5/3 exponent. At any given wave number (for $k < 1.0\ m^{-1}$), the spectral estimates for temperature increased with heat flux and decreased with height. In the case of humidity (for $k < 0.4\ m^{-1}$) the spectral estimates increased with increasing latent heat flux and

decreased with height. In the region of large k, the estimates in respect of temperature and humidity were nearly all equal.

The Fluxatron, the instrument designed as a simplified and improved version of the Evapotron, has again operated successfully under a variety of conditions. During the Wangara expedition fluxes obtained from it agreed well with those calculated from temperature and wind gradients and also with those from energy balance considerations. Work on the development of a suitable water vapour sensor is continuing. The normal nickel resistance wet bulb thermometers employed in the Evapotron are satisfactory only for relatively low frequency response.

Based on the Fluxatron technique but still in the experimental stage, an instrument designed to measure momentum transfer was tested during the Wangara expedition. The results, whilst correlating well with estimates of shearing stress obtained from wind gradients, were about 40% low. The deficiency has been traced to the electronic multiplier used; it is proposed now to replace this with a commercial type analogue multiplier.

To complement the temperature gradient equipment developed some years ago, a portable battery operated instrument has been built. Not only is the integration continuous but it provides a direct readout in terms of mean temperature gradient. The unit is somewhat less accurate than its more elaborate predecessor, but will undoubtedly meet many requirements where simplicity and reliability are the principal criteria.

In anticipation of a forthcoming expedition, during which the pattern of surface airflow associated with thermal convection currents will be investigated, a rapid response, highly sensitive wind speed and direction recorder has been developed. The latter comprises an expanded foam airfoil section vane, coupled to a low torque potentiometer, and capable of operating at wind speeds down to 30 cm sec^{-1}. The anemometer is basically a cup type instrument employing two sets of three cups, one

offset with respect to the other, driving a small electrical generator. Starting speed is 30 cm sec^{-1}.

To obtain a measure of the airflow in a vertical plane, a sensor, not unlike a wind direction indicator on its side, has been developed: a light weight vane, as described in the preceding paragraph, actuates an extremely low torque (0.1 gm cm^{-1}) potentiometer, the whole being mounted on a vertical axis about which it is free to turn. The instrument is kept into wind by a second vane whilst the two electrical outputs representing vertical inclination and azimuth are taken off via slip rings. The unit will be used in conjunction with a propellor-vane wind speed fluctuation sensor to record simultaneously the three turbulent velocity components.

V AGRICULTURAL METEOROLOGY

Elucidation of the exchange processes between the atmosphere and the soil-plant system constitutes the main long term aim of the Agricultural Meteorology Group. Current work also includes the further development of techniques to measure evaporation and formulae for its estimation and methods of reducing crop evaporation without harmful side effects. The Division maintains a comprehensive observational programme, including measurements of evaporation from a potato crop, pasture, bare soil and free water surface - and also of net radiation, ground heat flux, soil and leaf temperatures, air temperature and humidity, together with wind speed and various indices of soil and plant moisture status.

Evaporation - Its Measurement and Estimation

Evaporation is measured primarily by means of twelve large (6-ton) lysimeters, each 2 m^2 in area and 1.1 m deep. Most of them have precision balances, weighing continuously and automatically to one part in 140,000, and resolving evaporation to within 0.02 mm.

Trials with the hydraulic/pneumatic lysimeter referred to in earlier reports are now

practically complete. The first of these instruments to be used outside the Division, at Melbourne University's Experimental Farm (Mt. Derrimut), has completed 18 months of satisfactory operation. A second unit has been installed in Tasmania to assess irrigation requirements, and a third is about to be set up in Western Victoria. These are the first of an Australia wide network of ten such instruments being installed and operated by the Bureau of Meteorology.

To permit unattended operation, an automatic recording device has been developed for the hydraulic lysimeter. This provides a digital printout at regular intervals, the frequency of which can be adjusted at will. Proving tests are under way.

As part of a programme aimed at developing simpler lysimetric techniques, the Division, in cooperation with the Meteorology Department, Melbourne University, has installed a new type of monolith weighing lysimeter, also at Mt. Derrimut. The design permits a complete instrument to be built in the field, around an undisturbed block of soil, without having to use elaborate equipment. Two similar lysimeters are in the process of being set up, one in Egypt and one at Aspendale.

A modified form of the well-known Bowen ratio method of determining evaporation forms the basis of a new automatic instrument known as an energy partition evaporation recorder (EPER). Initially the temperature differences required were measured by sampling sequentially at two heights above the crop canopy but it was found that diurnal temperature changes led to errors. The instrument has since been adapted to sample simultaneously at two levels. Development is continuing.

A combination-type formula developed for estimation of evaporation takes into account not only the availability of energy at the surface but also the diffusive processes operating in the adjacent air, via an atmospheric conductance (h), and the movement of water through the soil-plant system, via a crop internal conductance (h_i). With many types of crop,

when soil moisture is plentiful, h_i is large and imposes little restriction on evaporation, which then takes place at the potential rate. This may be estimated from atmospheric variables alone. Under the same atmospheric conditions, potential evaporation from potatoes is found to be up to 20% higher than that from pasture, due amongst other things to h being higher for the relatively rough surface of the potatoes than for the smoother grass.

As the soil dries out however, h_i diminishes, and in so doing begins to exert a control on evaporation, which must be taken into account in relating actual to potential evaporation rates. Since h_i cannot be measured directly, it must be inferred from other parameters. Estimates of h_i, based on daytime averages of the variables concerned, have been related successfully to soil moisture potential.

Under non-potential conditions, when h_i can be most accurately determined, its value for pasture is found to be significantly higher than for potatoes, although both values decrease with diminishing soil moisture at about the same rate. This means that after some days of drying out of the soil, actual evaporation becomes less for potatoes than for pasture under the same atmospheric conditions. The reason is believed to lie partly in differences of effective root depth between the long established pasture and the newly established potato crop.

Under conditions of high evaporative demand, stomatal control was sometimes found important even when soil moisture was plentiful. On such occasions, h_i, and hence evaporation also, were assessed more reliably from the moisture status of the plants themselves than from that of the soil. Relationships between h_i and plant moisture status were found, in fact, to apply quite well for periods even as short as an hour.

Transpiration Reduction

Glass-house trials, with emphasis on aspects

relevant to proposed field trials, have again demonstrated effective suppression of plant transpiration by chemical treatment of foliage. Additional silicone and fatty alcohol compounds have been found to reduce transpiration under conditions of both plentiful and periodically restricted water supply - often by 20%, sometimes by as much as 40%. One of the materials, a fatty alcohol compound, has been effective also in suppressing evaporation direct from the soil, thereby reducing overall evapo-transpiration by a further 10 to 20%.

The increased internal resistance to transpiration which is brought about by such treatments could be expected to represent a higher proportion of the total resistance when the plants are in moving, rather than still air. This was confirmed in glass-house trials when fans were used to stir the air. For the same reason, treatments were sometimes more effective when plants were widely spaced.

Blue Mould in Tobacco

This work, which was carried out in conjunction with the Victorian Department of Agriculture at the Tobacco Research Station, Ovens, has been discontinued because the low degree of incidence of the disease in this area over the last few years has made it impossible to obtain firm results.

Such conclusions as can be drawn indicate that the programme of spraying being tested (based on a theoretical model developed in this Division coupled with forecasts obtained from the Commonwealth Bureau of Meteorology) can give good protection.

Other

As mentioned in last year's report, this Division has collaborated with the C.S.I.R.O. Division of Irrigation Research, Griffith, in making measurements at Coleambally, New South Wales, to evaluate the effect of irrigation on climate. The extraction of the three years' data from the instrument records has now been completed, and it is

anticipated that preliminary results will appear in next year's report.

VI RADIATION

Reference was made last year to the completion of a comparison, carried out under the auspices of the C.I.M.O. Working Group on Radiation Instruments for General Use, of four types of net pyrradiometer, one being the instrument designed in this Division. The results obtained, together with those from similar tests carried out at Hamburg, Leningrad and Poona, are being analysed by the Government of India Meteorological Department at Poona.

The Xenon arc laboratory short wave radiation source is now operating satisfactorily. Approval from the National Association of Testing Authorities will shortly be sought to use this source for calibrating pyranometers and net pyrradiometers. Such calibrations are at present carried out using the sun as source, but the number of suitable days per year is insufficient to cope with the increasing number of instruments being received.

The suntracker mentioned in last year's Report has been put into operation. It is used to train a pyrheliometer onto the sun continuously, to measure direct beam solar radiation. In accordance with W.M.O. recommendations, this parameter is now recorded routinely by automatic data logging equipment.

Some progress has been made in developing an instrument to measure, directly and continuously, net long wave radiation, a quantity hitherto evaluated by taking the difference between net radiation (all wavelengths) and short wave radiation balance. The technique is to enclose a net pyrradiometer in a spherical sheet of black polythene which acts as a long wave band pass filter. The effect of differential heating due to incident short wave radiation is eliminated by rotating the filter. The instrument can also be made in a uni-directional form by enclosing one side with a fixed temperature cavity. Theoretical computations of the effect of cloud cover on the net long wave radiation loss at

the earth's surface are being carried out concurrently.

The ultra-violet component of solar radiation is of current interest in studies of skin cancer and also of degradation of materials, particularly plastics. The intensity of global ultra-violet radiation is measured routinely at Aspendale using a suitably modified pyranometer. A similar instrument has been constructed for the University of Papua and New Guinea. This will be installed at Port Moresby but, being portable and battery operated, will be available for short period surveys in remote parts of the Territory. Also, ultra-violet radiation recording equipment built by the University of Queensland continues to be operated at Aspendale on their behalf. It is one of a chain of three instruments, the others being in Brisbane and New Guinea.

In connection with Radiation environment of plant communities, some measurements of global and net radiation gradients have recently been commenced in a pine forest in the Dandenong Ranges. A miniature pyranometer and net pyrradiometer have been used, with suitable arrangements to hoist them through the canopy.

The spectral distribution of radiation in the visible wavelengths is of importance in studies of the efficiency of energy conversion in plants. The monochromator equipment designed to measure this distribution has been calibrated and is operating satisfactorily. Development of a computer programme capable of dealing with the monochromator output presented some difficulties but these have now been largely overcome and it is anticipated that routine recordings will commence shortly.

VII MISCELLANEOUS

Aircraft Design and Wind Gusts

The effect of wind gusts gives rise to a number of problems in aircraft design concerned both with structural strength and the maintenance of

control. For this reason, information on gusts is always required by aircraft designers. Observations of vertical air velocity obtained from an aircraft belonging to the Division of Radiophysics have been related to simultaneous measurements of wind velocity, wind and temperature gradient and net radiation. The results can be classified according to the stability of the atmosphere, though in all cases the distribution of gust velocities is very different from the Gaussian form. In stable conditions the r.m.s. vertical velocity decreases with increasing stability, the phenomenon being more marked at greater heights. However, there appeared to be no direct connection with height alone. In contrast, under unstable conditions, the r.m.s. vertical velocity increased with height but - rather unexpectedly - was found to decrease as the temperature gradient intensified. The latter effect probably arises from wind shear.

In the absence of more precise information, Aeronautical Engineers make use of a so-called "derived gust velocity" calculated solely from the aircraft's vertical acceleration: if this is compared with measured gust velocity it is found that when velocities are low the derived values are over-estimated and, when high, under-estimated.

Bush Fires

Each year bush fires cause great damage to Australian forests. However, the losses could be considerably reduced if more were known about the behaviour of fires in various weather situations. To this end, in collaboration with the Division of Industrial Chemistry, upper winds measured by pilot balloon and temperature soundings from aircraft have been obtained in the vicinity of five forest fires. Using only those occasions when the wind was reasonably steady, the measured amount of heat carried away by the wind was found to agree well with the computed amount released by the fires, the wind removing the energy uniformly at all levels.

It was thus possible to confirm the estimates of fuel quantities and burning rates on which the calculations were based.

Turbulence records, relating to scales of some hundreds of metres, showed a clear difference between air motions inside and outside the smoke plume - both r.m.s. and mean vertical velocity being greater inside; however, this difference was not apparent in air motions of very much smaller scale.

Should more intense bushfires provide the opportunity it is hoped to carry out further work during the coming summer.

Computing

This year the computation and data processing group has been largely concerned with processing observational data from the Wangara expedition. The data from six thousand balloon flights, and about eight hundred radiosonde flights, together with micrometeorological records, were punched on about eighty thousand cards during and after the expedition. The processing of the radiosonde and micrometeorological data has been completed, but in the case of the pilot balloon figures the eradication of observational and punching errors necessitated transferring the data temporarily to magnetic tape. Most of this preliminary checking is now finished and the computations proper are going ahead.

Other investigations in which the group has assisted include the following: the distribution of radar echoes, the trajectories of GHOST balloons to determine their poleward drift, variations in atmospheric turbidity, the general circulation between five and thirty mb, and a theoretical study in stratospheric diffusion.

The Division has purchased a multichannel analogue magnetic tape recorder, for data acquisition both in the laboratory and on field expeditions. The recorded tape is suitable for automatic processing, by either analogue or digital computer. Its main application will be to record turbulent or other rapidly fluctuating quantities which make manual following a prohibitive task.

A new analogue/digital conversion system is

being built which will greatly facilitate the automatic processing of data. It will supersede the system at present in use in which chart records are manually followed and converted to digital form on punched paper tape. The new system will accept analogue data, either from manually followed paper charts or analogue magnetic tape, as well as digital data from both typewriter and punched paper tape. It will reproduce these on digital magnetic tape in a form suitable for direct reading into a computer.

Instrument Development

The Drawing Office has as its major function the provision of a mechanical instrument design service for the Division. The following are examples of the more important instruments developed during the course of the year.

A "Sun tracker", essentially an instrument stand which continuously and automatically positions itself with reference to the sun. Normally a complex system of precision gears and cams is needed to cope with the slight irregularities of the sun's path; in this case, however, two simple solar cells operating in vertical planes mutually at right angles are employed to control an inexpensive gearbox.

In measuring diffuse (sky) radiation, it is standard practice to use a fixed shade to shield the sun's disc from the solarimeter. This however blocks out some of the radiation being measured and to overcome this an occulting disc has been devised. Essentially, it consists of a small disc moving in an arc, the plane of which is adjustable.

Reference was made in last year's Report to the effect of sea surface temperature on large scale variation of rainfall in adjacent regions and to the proposal to develop a suitable buoy to measure sea temperature. Since then, two prototype buoys have been developed, this Division being responsible for the mechanical design of the buoy, the Bureau of Meteorology for the electronics (including reception), and the Division of Fisheries and Oceanography for the anchorage. Preliminary

trials five miles off-shore in Port Phillip Bay have given satisfactory results, and reliability tests will be continued for another twelve months.

Additional sensors for the "Sumner" long term recorder continue to be made available. At the request of the U. S. Geological Survey Department, a barometric pressure unit suitable for use up to altitudes of 20,000 feet has been designed and produced.

To meet the research needs of the Division, many different types of instruments are designed, ultimately appearing as prototypes in the machine shop. Of these, some are of interest to other workers both in Australia and overseas, and therefore of industrial value. Where new ideas are involved patents are taken out, but in either case the instrument frequently goes into commercial production. Currently, there are twelve patents in force and a total of seven types of instruments being manufactured.

General

The Division is an accredited laboratory of the National Association of Testing Authorities in the fields of low speed anemometry and atmospheric radiation instruments. In the case of the former, the annual calibration rate - which grows continuously - now amounts to over one hundred instruments a year, from both Commonwealth and State Governments as well as from industrial and commercial firms. The number of radiation instruments handled has again increased by about a quarter over last year's figures and is now reaching such proportions that plans are being contemplated to make the calibration process an automatic one. Already a computer programme has been written to scrutinize the figures obtained from the low temperature black body source and to evaluate the sensitivities.

The new wind tunnel and ancilliary facilities have been made available to an officer of the Division of Irrigation Research, Deniliquin. The work has been concerned with problems of soil erosion as related to size, shape and distribution of

obstructions.

During cloud seeding flights organized by the Victorian State Department of Agriculture, radar monitoring was carried out to track rain echoes in the vicinity of the seeding area. Observational data in the form of notes and rain echo photographs were made available to the Department.

Two Fluxatrons, a description of which appears elsewhere in this report, have been loaned; one to the Division of Land Research, Katherine, N.T., and one to the University of Washington, Seattle.

VIII ACTIVITIES AND PERSONALIA

Meteorology is inherently international in nature, and continues to grow rapidly in terms of its associations with other disciplines. Members of the Division have maintained their connection with various organizations, 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.

During the year Mr. W. C. Swinbank and Dr. A. J. Dyer were jointly awarded the Royal Meteorological Society's Buchan Prize. This award is a biennial one and is made in recognition of the most important original contributions to meteorology published in the Quarterly Journal during a five-year period.

In 1967 the Chief of the Division, Dr. C. H. B. Priestley, was elected Vice-President of the International Association of Meteorology and Atmospheric Physics and appointed a member of the newly formed Joint WMO/IUGG Organizing Committee of the G.A.R.P. (global atmospheric research programme). In March he attended the first meeting of the latter and the fifth meeting of the WMO Advisory Committee, both at Geneva, visiting en route and lecturing at meteorological institutions in the U.S.A., United Kingdom, and Hong Kong.

Early in the year, Mr. W. C. Swinbank returned from twelve months' leave of absence in the U.S.A., where he spent five months as Visiting Professor at the University of Hawaii, and two months at the University of California, Los Angeles. He was also a Visiting Scientist at the National Centre for Atmospheric Research, Boulder, for a period of three months. In September he attended as Australian delegate the XIVth General Assembly of IUGG at Lucerne and presented papers to the IAMAP on behalf of himself and Mr. E. K. Webb. At this meeting he was appointed Consultant to the Inter-Union Commission for Radio Meteorology.

From September, 1967, to May, 1968, Mr. E. L. Deacon occupied a position as Visiting Professor at the Texas A. & M. University.

From January to July of this year Dr. A. J. Dyer was on study leave at the Department of Atmospheric Sciences, University of Washington. His work has two aspects; circulation systems of the stratosphere and atmospheric fine structure in the lower layers.

In January, 1968, Mr. I. C. McIlroy returned from a year's leave of absence with the WMO, during which time he assisted the Egyptian Meteorological Department in setting up an Agro-meteorology Section in the new Meteorological Institute of Research and Training, Cairo.

Dr. D. E. Angus continued to give a course of lectures in micrometeorology at Melbourne University, but terminated it at the end of the 1967 academic year as a result of impending leave of absence. Two months later he took up a three-year appointment as Reader in Environmental Physics in the Botany Department of the University of Queensland.

Dr. R. Roth of the University of Munich is spending a year in the Division working in the field of atmospheric turbulence.

Dr. T. Schneider from the Agriculture University, Wageningen, recently commenced a two-year Fellowship in Agricultural Meteorology.

Mr. E. J. Yanaz D. from the Central University of Venezuela spent a month in the Division becoming familiar with all aspects of the Evapotron and Fluxatron. Basically concerned with hydrology, he hopes to employ the techniques embodied in these instruments on his return.

In collaboration with the Victorian Department of Agriculture, two films on Agricultural Meteorology were produced and were subsequently screened on the country television network.

IX PUBLICATIONS

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X STAFF

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