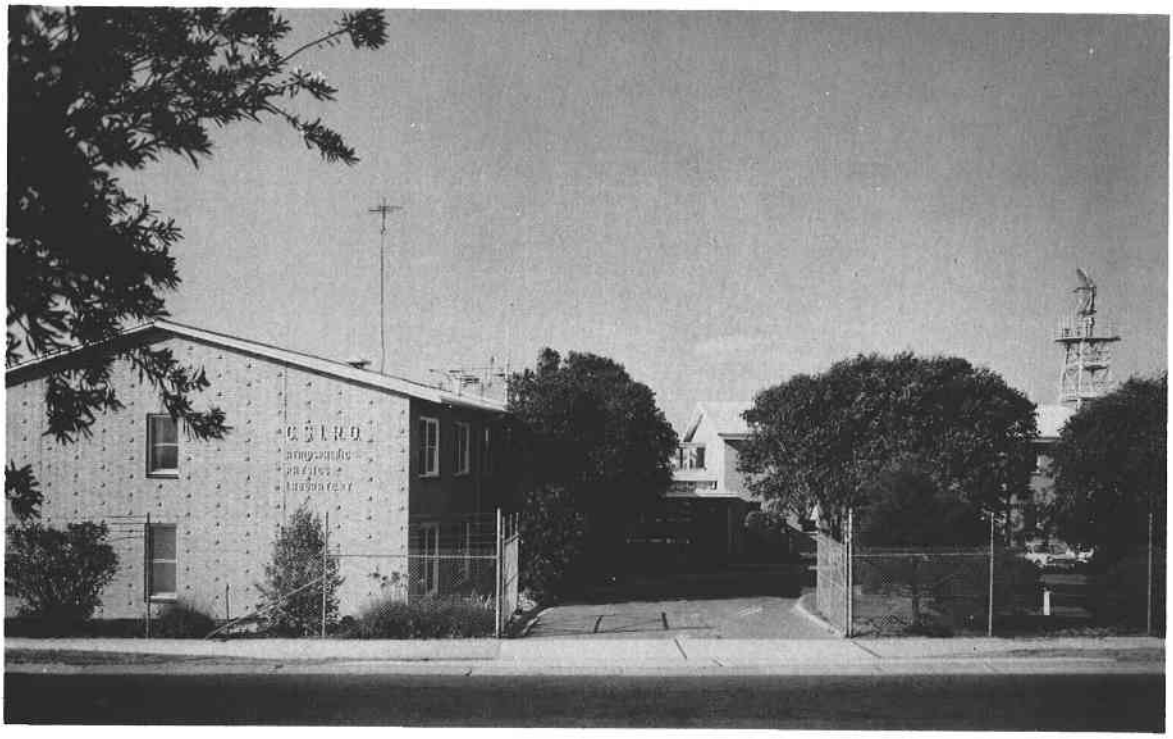

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ANNUAL REPORT 1972-73

Division of Atmospheric Physics

Commonwealth Scientific and Industrial
Research Organization, Australia
Melbourne

CONTENTS

DIVISION OF ATMOSPHERIC PHYSICS

ANNUAL REPORT

1972 - 1973

INTRODUCTION

Last year's annual report opened with a brief stocktake of progress during the Division's 25 years of existence (1946-71). This year it is appropriate to focus on some of the newer developments taking place.

One of the principal mainstays of the Division's research policy has been to avoid temptations to undertake ad hoc investigations and to adhere to the belief that most problems are best solved by first gaining a thorough knowledge of the fundamental physical processes at work. A good example of the value of this approach relates to airborne pollutants and their dispersal. Understanding rests solidly on a knowledge of atmospheric dynamics and turbulence - two subjects which have been studied intensively in their own right since the Division came into being.

Looking ahead there are three areas which call for special attention.

Air/Sea Interaction and its role in Geophysical Fluid Dynamics.

Much has been learnt in the past of the mutual interaction between the atmosphere and the underlying land surface. Yet knowledge of the important links between the atmosphere and ocean as well as the behaviour of the ocean itself (which occupies three quarters of the earth's surface in the Southern Hemisphere)is scanty.

To enable measurements to be made close to the air/sea interface, a substantial observation platform standing in 10 m of water has been erected in Port Phillip Bay about 1½ km off shore from Aspendale. Also a programme involving instrumented drifting ocean buoys is under way. At the same time, the creation of a small geophysical fluid dynamics group will undertake valuable complementary studies of the not dissimilar dynamical problems of atmosphere and ocean.

Atmospheric Chemistry

There is a clear need to embark on a programme of atmospheric chemistry in order to understand the composition of the atmosphere and the mechanisms of balance or imbalance. A start in this direction has already been made with the establishment of our CO_2 monitoring programme.

In this context we look forward to the establishment in Australia of a 'base line' station, along the lines of the World Meteorological Organisation's recommendation, capable of sustaining a long term series of high quality observations. The constituents of the atmosphere under examination would be those of which a knowledge is essential to the well-being of man and his habitat.

Numerical Simulation of Atmospheric Processes

Finally, the considerable value of a close inter-relationship between the Commonwealth Meteorology Research Centre (CMRC) and the Division at Aspendale, in terms of progressive scientific advancement, is becoming apparent. In several areas of active development the two groups are symbiotic. Collaborative experiments are being planned in which physical processes and phenomena studied at Aspendale will be represented in the numerical models developed at CMRC with a view to quantitative assessment of their significance in weather and climate.

I DYNAMIC AND SYNOPTIC METEOROLOGY

One of the chief interests in this field has for some years been simulation and prediction of global scale atmospheric behaviour.

The problem may be divided into two parts - medium range behaviour (of a few days to a week or two) where current physical and hydrodynamic reasoning is yielding considerable success; and longer term behaviour (months, seasons, years) where suitable techniques have not yet been formulated and which contains most important implications for human life.

The first part of the problem is being attached with vigour in Australia and elsewhere; the latter part is receiving increasing recognition in scientific planning.

The Atmospheric Boundary Layer

For medium range simulation and forecasting it is necessary to take into account in an adequate manner the effects of small scale turbulent eddies, which bring about transfers of properties, especially in the boundary layer, where interaction occurs between atmosphere and underlying surface. In the longer term seasonal or climatic problem, proper knowledge of processes in the boundary layer is likely to be even more vital.

Past Annual Reports have referred to our successful "Wangara" field expedition to Hay, N.S.W. in 1967. Data from it are being used by a considerable number of institutions around the world as well as ourselves, to improve boundary layer theory. At this juncture it would be useful if the experiment could be repeated at a different latitude and in a region of different surface roughness conditions. To this end a field expedition is planned for July next (1974) to Daly Waters in the Australian tropics. In contrast to Hay (latitude 34°S) where the surface was grass some 5 to 10 cm in height, the new site is at 16°S and has a uniform

cover of open forest some 5 to 7 m high.

A slightly different problem is that of specifying fluxes of heat, momentum and water vapour over the oceans. This is of importance not only to weather and climate but also in other applications, such as the generation of surface waves, tilt of water surface and drift current, relevant to predicting the movement of surface contaminants such as oil slicks. It has been found possible to adapt the similarity theory of Kazansky and Monin to the combined boundary layers of atmosphere and ocean. The theory predicts the value of surface stress and the drift current when external conditions are given, viz latitude and geostrophic wind.

In this context the data collected during the Wangara experiment has been particularly useful. Previous work carried out in the Division on drag coefficients over the sea and the effect of thermal stability has enabled the tentative evaluation of the functional form of two previously undetermined parameters describing flow over the sea. Further work in this area will be of relevance to the Commonwealth Meteorology Research Centre where there is a need to satisfy more precisely the boundary layer conditions being used in large scale models.

The Seabreeze

Successful numerical simulation of the seabreeze has led to further experiments to test the effects of varying large scale pressure fields, surface roughness and latitude on the development and inland progression of the seabreeze front.

Methods of treating moist convection by profile adjustment have been explored and significant success achieved in simulating transfer of moisture and heat from warm sea to cold air by convection. Attempts to simulate tropical convection have so far been less successful. A solution of this problem is regarded as a necessary prerequisite to an attack on the moist seabreeze

and also tropical cyclones.

Convective Storms

Field observations by radar of convective storms has continued. A specific purpose has been to examine the self-seeding of clouds by injection of large ice crystals originating in the upper reaches of cumulonimbus clouds. Evidence has been collected that this mechanism can be important in developing thunderstorm situations.

A related problem has been the investigation of the part played in hail formation by variations in the transport of freezing nuclei in the sub-cloud layer. Results indicate that changes in the supply of nuclei accompanying cloud growth affect the microphysics of hail production.

Statistics of Frontal Passages

Ten years' synoptic maps have been processed, and statistics of frontal passages and concomitant weather compiled for a number of points on the Australian continent. Relationships are being sought between the various elements, for example, rainfall and wind and temperature change, with a view to improving forecasting capability.

Estimating Steam Fog produced by Power Stations

Electrical power grids in Australia have now reached such proportions that environmental impact assessments are a necessary part of planning. Fog effects associated with the discharge of waste heat in large water bodies were studied in connection with the proposed Newport Power Station on Hobson's Bay. The results were interpreted against the climate of naturally occurring fogs. In the course of this study, general procedures for estimating significant steam fog effects were developed. Advice on the handling of such problems has been provided to the State Electricity Commission of Victoria with special reference to a new project in the Latrobe Valley.

TECHNICAL ASSISTANCE TO THE DIVISION OF ENTOMOLOGY

Two members of the Division have given substantial assistance to the entomologists, who are concerned with understanding the migrations of insects, mainly plague locusts. A frequency modulation system has been developed for a mobile 3 cm radar and help given in relating radar pictures of locusts to movement of the insects.

GENERAL CIRCULATION AND CLIMATE

Earlier work has shown that the mean latitude of the subtropical high pressure belt is a convenient index of the general circulation. Evidence for global meridional interactions on seasonal and short term scales between stratosphere and troposphere have been discovered. The possibility of applying these findings to problems of seasonal and long range forecasting is now being explored.

Studies of the 100 mb level stratospheric temperature anomalies found in the Australian region in 1963 and 1966 suggest that the 1963 anomaly was due to local heating caused by volcanic dust in the atmosphere. The 1966 case was more probably a circulation anomaly. Further work on this hypothesis will be undertaken by the radiation group in conjunction with the numerical modellers at CMRC, and later utilized in further studies of climate.

II GEOPHYSICAL FLUID DYNAMICS

Laboratory Modelling Facilities

Increased use is being made of quantitative visualization in experiments. A Schlieren system incorporating two 31 cm spherical mirrors is being successfully used in stratified fluid studies, giving a sensitive detection of weak density disturbances. A closed circuit T.V. system is being used, in which two or more cameras provide a combined three-dimensional view of a stationary or

moving experiment. The view is recorded on ½ inch tape and replayed for analysis. A pointer image superimposed on the picture is used to provide coordinate measurements for on-line data reduction by computer.

This is apparently the first application of the technique in fluid-mechanical studies, and hopefully will simplify enormously the acquisition and interpretation of motion measurements in complicated flows.

Angular momentum mixing

Last year's report described experiments demonstrating that angular momentum could be diffused by the turbulent mixing of a fluid system in uniform net rotation. The result of such mixing is to produce an average rotation greater than that of the boundaries.

Analysis of the data has indicated that the momentum diffusion is accomplished by the interaction between wave-like and 'viscous'-like components of the turbulence. If the 'viscous' component is great enough the presence of waves produces a most efficient momentum transfer, but without waves no angular momentum would be transferred. Preparation for further experiments on the structure of rotational turbulence is under way. Their ultimate purpose is to provide a more rational description of the effects of rotation on large-scale atmospheric diffusion.

Parametric instability of internal waves

Theoretical work has predicted that in a stably stratified medium, as constitutes most of the atmosphere and the upper ocean, propagating or standing internal waves are intrinsically susceptible to growing disturbances of finer vertical scale. The result is that such waves may lose their coherence at modest amplitudes, much lower than would be required for the violation of conventional conditions for stability against shear or gravity.

In the absence of factors restricting the form of the disturbances, these are likely to have a period twice as long as the wave on which they grow, but if they pre-exist or are restricted in form, the possibility for growth upon the wave depends, in a predictable manner, upon their frequency.

Experiments have accurately confirmed the theoretical predictions. A 'background' wave field, created by swinging as a pendulum a cylindrical container filled with stratified salt solution was found to become unstable at the predicted amplitude (see figure A). Small scale, shallow angle, steplike distortions develop in the density profile, suggesting that the mechanism may be one important means by which steps in density as are commonly observed in the ocean and atmosphere, may continually be created.

Shear Flows in Stratified Media

As a theoretical basis for experiments on the transmission and absorption of waves generated near the ground and transmitting into a shearing wind, some theoretical work has been done on the dispersion of such waves, and on the propagation of shearing disturbances. These disturbances travel from their source at a constant speed, and form a 'front', the width w of which can be expressed as $w \propto t^{1}/_{3}$, where t = time from initiation.

Boundary Layer Instabilities

A significant proportion of the energy lost by oceanic tides is due to the friction of the water as it moves against the bottom, not only due to the tide itself, but to internal waves beneath the surface. As a first step in understanding momentum transfer near the boundaries of a moving stratified fluid an experimental and theoretical examination of the stability of a boundary layer in a vertical oscillatory flow has been carried out. It has been found that for oscillation frequencies near the natural buoyancy (Viäsälä-Brunt) frequency, the

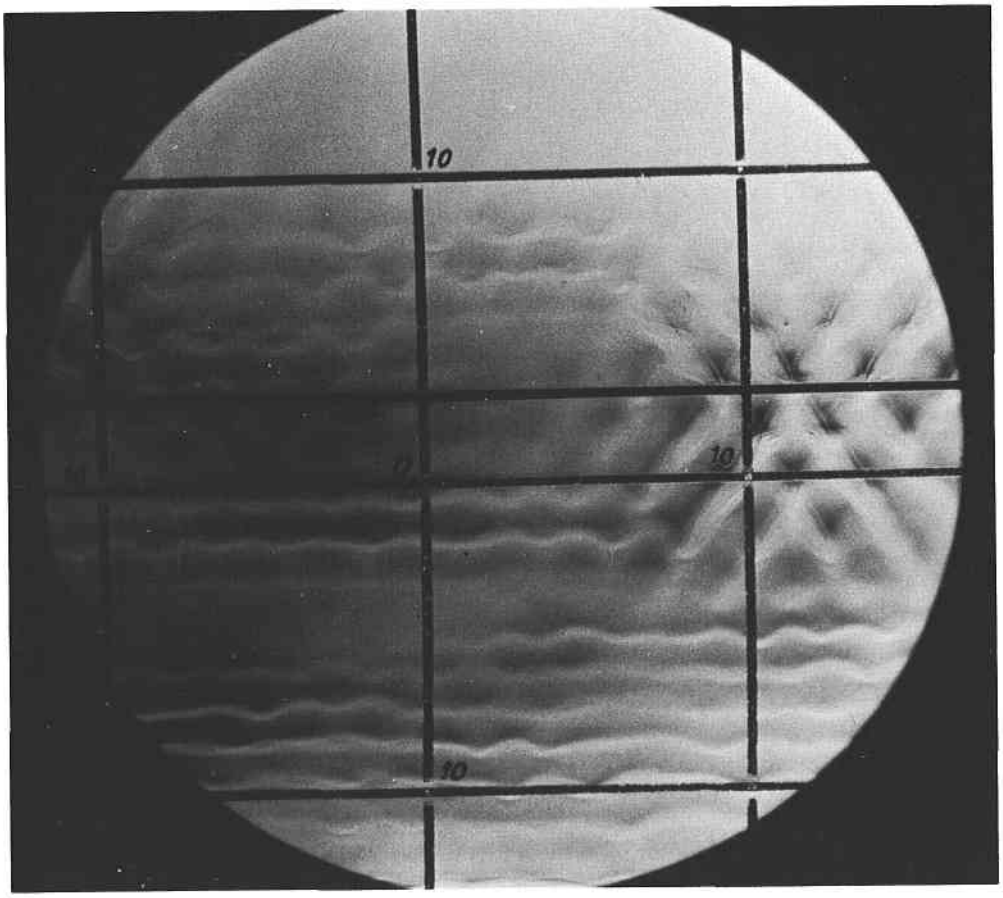

Figure A. Boundary layer instability in a stratified medium, the density increasing continuously with depth. The boundary layer on a vertically oscillating glass plate is undergoing a transition from a horizontal wave instability (left region of figure) to a diagonal wave instability (right region). Changes in density gradients within the layer are revealed optically.

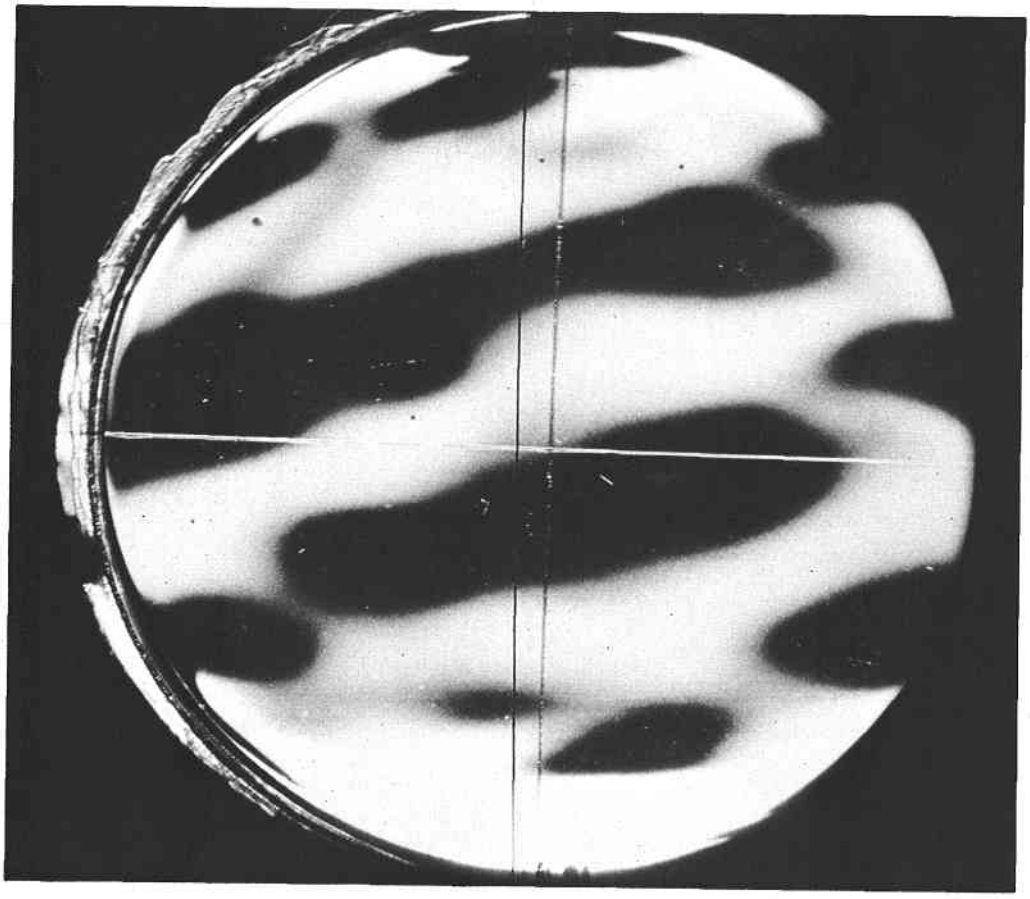

Figure B. Laboratory experiment showing parametric instability. A view is shown through a cylindrical container filled with salt-stratified water. The container forms part of a pendulum swinging in the plane of the figure. The instability, which appears as areas of light and dark, is revealed by an optical technique. These areas represent changes in density gradient, and develop later into discrete layers. Similar instabilities may be a cause of layering within the atmosphere and the ocean.

boundary layer is particularly unstable, but on either side of this frequency the stability increases. In the experiment two distinct and previously unrecognized regular modes of instability are observed (see figure B), depending on frequency and amplitude.

To provide the capacity for modelling rotational effects, a laboratory turntable 0.75 m diameter with precisely controlled speed over a range 0 - 120 R.P.M., is under construction.

Internal Tides in the Ocean

Oceanic internal tides, i.e. internal waves with tidal periods of (approximately) 12 and 24 hours, are generated by the interaction of surface (or barotropic) tides with bottom topography such as continental slopes, ridges and abyssal hills. These internal waves are important for three main reasons. Firstly, they may have considerable amplitude and hence cause significant horizontal motions in the ocean. Secondly, they extract energy from the surface tide and therefore are an important factor in the long-standing question of the location and nature of the dissipation of tidal energy. Thirdly, theoretical considerations based on the properties of internal waves interacting with bottom topography indicate that internal tides may be the source of significant vertical mixing in the ocean, particularly near the top of continental slopes. Such mixing may have significance for local dynamics of the region and for biological processes which depend on vertical transport.

Numerical models based on new formulations of the appropriate conditions for the radiation of wave energy have been developed for the calculation of internal tidal wave fields generated by continental slopes and other two-dimensional topographic forms, with realistic oceanic density stratification. Attention has been focussed on continental slopes, since these, because of their height, are the most effective internal tide generators. The direction of rays

of internal wave energy propagation in the vertical plane depend only on the wave frequency, the local buoyancy frequency and the Coriolis frequency. The character of the waves generated depends on the ratio of the slope of these rays to the topographic slope. In particular, if this ratio is mostly greater than unity most of the internal tidal energy generated is directed inshore on the continental shelf, whilst if it is less than unity most of the energy flux is directed out to sea. Both situations are common in the ocean. The degree of mixing implied by the models depends on the continental slope profile and the amplitude of the surface tidal motion normal to the slope.

III RADIATION - ATMOSPHERIC AND TERRESTRIAL

There are three general objectives underlying the work of the radiation group. These are:

1. To maintain expertise in all aspects of atmospheric radiation.

2. To maintain and refine our roles as the national and international calibration and standards laboratory for radiation instruments and as a radiation observatory.

3. To maintain an active research programme in which the central interest is in the interaction of cloud and atmospheric radiation. Other activities include programmes on the prediction and monitoring of solar UV radiation, the monitoring and interpretation of atmospheric turbidity and the use of passive microwave remote sensing of ground surface characteristics such as soil moisture content.

Radiative Properties of Cloud

An aircraft expedition was undertaken in collaboration with the Cloud Physics Division in February to investigate radiative properties of Ac and Sc cloud decks off the coast near Merimbula in

N.S.W. The object was to extend the number of experimental case studies obtained in earlier years in order to check theories relating cloud microphysics to the associated radiation fluxes. Work on combined lidar and radiometric observations was extended to include various middle level cloud systems and confirmed, amongst other things, that middle level cloud is often far from optically "black" to long-wave radiation and that physical thickness of such cloud is not often a good indicator of its optical thickness (or "blackness"). It has also been found that the emissivity of cirrus cloud measured by satellite IR instrumentation correlates well with ground-based observations.

The results of much of this work will be of relevance to modellers in the Commonwealth Meteorology Research Centre. If the radiative features of either particular cloud types or cloud systems can be catalogued it will open the way for numerical models of the atmosphere to begin incorporating details of the radiation field.

A theoretical investigation was made of the effect of atmospheric radiation on the gross character of Sc cloud. The theory predicts cloud thicknesses and dissipation times which agree well with those observed and demonstrates the importance of small shortwave solar radiation absorption which can occur in these clouds. Calculations of solar energy available at the surface (using detailed cloud cover information from 60 stations) have been made and solar radiation statistics for Australia have been produced.

Monitoring UV Radiation

The Division has collaborated with Queensland University in developing a simple and stable monitor of the UV radiation of importance to human skin cancer. It is intended to re-establish and maintain, in the long term, a network of such monitors in Australia - an exercise which has received fresh impetus in the light of the suggestion that supersonic aircraft may interfere

with the ozone balance in the upper atmosphere. In parallel with this, and as an addition to the observatory programme, a monochrometer is being developed for continuously monitoring the detailed spectrum of solar UV radiation.

Microwave Sensing of Natural Surfaces

All matter at a temperature above absolute zero radiates a continuum of electromagnetic energy, the intensity of the radiation depending on the temperature and emissivity at the wavelength concerned. For natural surfaces, the latter depends on various parameters such as soil moisture content and vegetation cover over the land, and wind, wave height and oil and foam cover at sea. Remote measurement of the amount of radiation emitted can, together with the surface temperature, thus provide much information about the surface under investigation and this year work has commenced on a programme to investigate the possibilities of remote measurement of soil moisture using microwave radiometry.

Observatory and Standards

Surface albedo, atmospheric longwave radiation, wet and dry bulb temperatures and wind speed and direction have now been added to the list of quantities continuously monitored. The new laboratory now under construction will also afford improved facilities for pyrheliometer measurements.

The number of radiation instruments received for calibration during the year was about 250, compared with about 350 for the previous year. The fall is largely due to a new policy whereby manufacturers have been encouraged to carry out their own calibrations under the Division's overall supervision, so reducing the load on Divisional facilities and developing expertise in the industry.

During the year two officers of the Indonesian Directorate of Meteorology and Geophysics brought the Indonesian National Standard

pyrheliometer to Aspendale for comparison with the Regional Standard. The Commonwealth Bureau of Meteorology also attended with their Angstrom pyrheliometer. Interchange of net pyrradiometers with the Atmospheric Environment Service of Canada has continued to maintain cross-checks of the respective long- and short-wave radiation standards.

IV MICROMETEOROLOGY

Air-Sea Interaction

Basic information on the turbulent fluxes of heat, momentum and water vapour at the air-land and air-sea interfaces is an essential requirement for numerical weather prediction. Whilst the air-land interface is reasonably well understood, our knowledge of air-sea interaction is limited - not only by the lack of a suitable theoretical framework, but also by the present use of a wide variety of experimental techniques (which leads to conflicting results) and the almost complete absence of reliable data at high wind speeds and over large fetches. We are now planning to investigate some of these problems drawing on the expertise developed in air-land research.

A rigid observation platform standing on the sea-bed has been erected in Port Phillip Bay. Radio telemetry links instruments to the Aspendale laboratory. The platform will enable turbulent eddy fluxes to be determined by the traditional eddy correlation method, and allow for the development of measurement techniques for use in the open ocean.

Plans are well advanced to construct and equip a number of spar buoys to be released in the open ocean south of Australia. Read-out will be via NASA's Nimbus F satellite due for launching in June, 1974. It is hoped to obtain data over a 2-year period. Eddy fluxes will be obtained by a spectral density method based on proving experiments conducted on the Port Phillip Bay platform.

The Division has been invited to participate in the Japanese air-mass transformation experiment

(AMTEX, February 1974) and it is proposed to measure eddy fluxes directly at three critical stations of the network in the South-West Islands of Japan, and to develop the use of the spectral density method referred to above, at these stations and on board a research vessel.

Work previously reported on estimating the rate of evaporation from saturated surfaces has been continuous using data obtained from oil rigs in Bass Strait and from the cruises of USNS "Eltanin". In general, results obtained to date tend to confirm the previous conclusion that the ratio of sensible to latent heat flux can be expressed in a form depending on the surface temperature alone. Individual observations, however, show discrepancies which require further investigation.

An important contribution in the measurement of water-vapour fluxes has been achieved by the development of fast-response infra-red hygrometer. Preliminary tests over land have been successful and the instrument design has progressed well beyond the prototype stage.

Thermal convection

On the expedition at Hay, N.S.W., in February 1970, a large volume of experimental data relating to thermal convection was obtained. The objective was to gain a better understanding of the mechanism of convection in the lower atmosphere, and in particular to elucidate how the small-scale convection currents in the lowest few metres or tens of metres give rise to the larger-scale thermals which extend up to heights of hundreds or thousands of metres.

Measurements included the average and turbulent fluctuations of velocity components and temperature up to 32 m. Thermals passing across the site were tracked in turn by gliders circling at heights between 300 and 1500 m, the glider position being continuously monitored on the ground by two azimuth recorders. The pattern of surface air flow

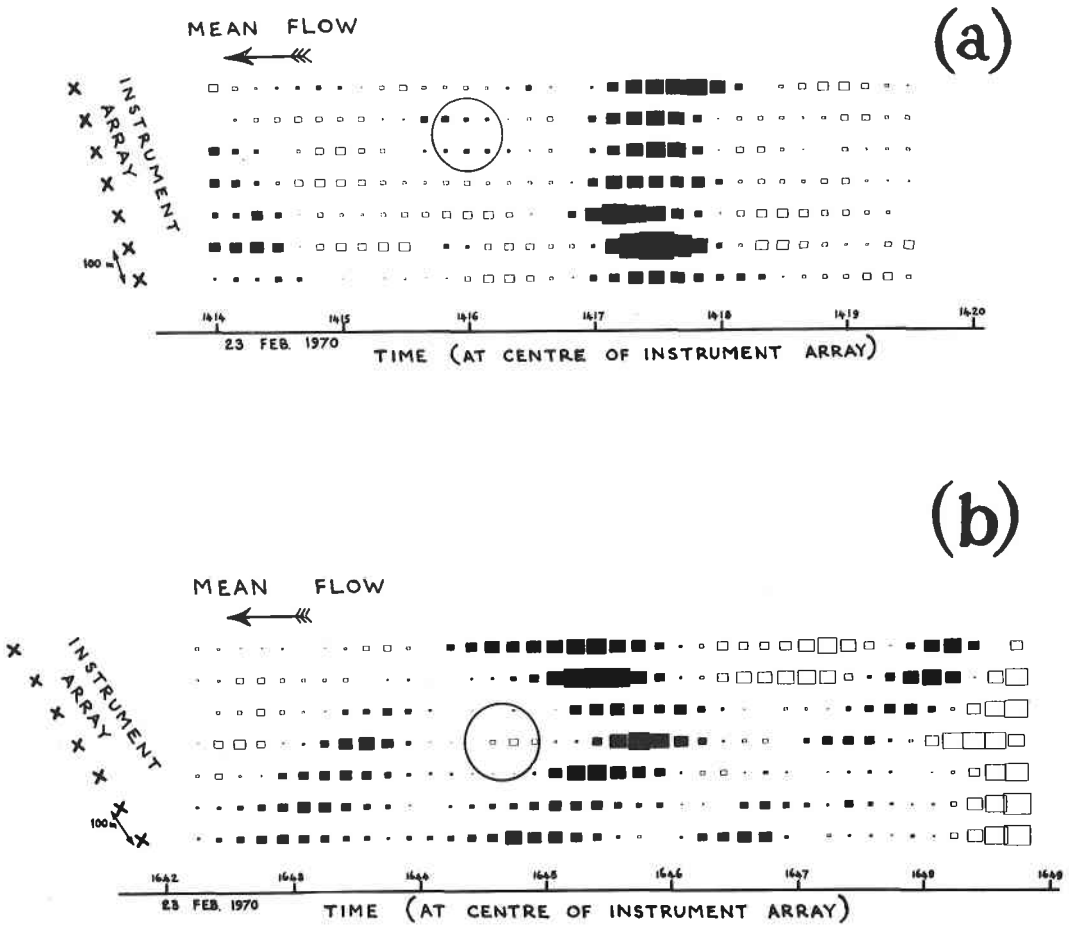

Figure 1. Patterns of longitudinal (i.e. along-mean-flow) surface convergence and divergence associated with the passage of a thermal. Lengths of rectangles (widths in proportion)indicate magnitudes of convergence and divergence represented as difference of longitudinal velocity component before and after a 30-sec interval centred at the time as plotted. Each diagram displays approximately the spatial pattern of convergence/divergence in the air stream passing across the instrument array.

was recorded by an array of seven wind speed/ direction instruments set at 100 m intervals across the wind direction.

The surface array results for a number of periods encompassing the passage of thermals have been processed. A plot of the vector deviations from the mean flow is obtained, and the corresponding convergence of the horizontal flow is also evaluated, separately for the longitudinal and transverse directions. Two examples of longitudinal convergence patterns are shown. Generally, when a thermal has passed (as indicated by a glider track), there is, after a delay of 1 to 3 minutes, strong longitudinal convergence along a line which extends right across the span of the instrument array (400 - 600 m). Usually the line is approximately straight, as in Fig. 1a, though it is not necessarily so, as illustrated by the curved shape in Fig. 1b. Thus, it appears that a thermal has the form of a "mini-front" near the ground, trailing after the upflow aloft, and commonly spanning about a kilometre laterally. Analysis of the lateral component of the flow suggests so far that this component has no systematic relationship at all with the thermal.

The relative contributions of the small-scale currents and the larger thermals to the fluxes of heat and other entities at heights up to 30 m are now being evaluated. It appears that even at heights as low as 30 m the contribution of a thermal to the fluxes is appreciable and perhaps even dominant in many cases.

V ATMOSPHERIC MONITORING

With the continued cooperation of Qantas and D.C.A. baseline monitoring of CO_2 has been continued using air samples obtained from aircraft. More than 500 flask samples obtained over a 15 month period have been analysed. Above an altitude of 3.5 km, remarkably little variation in CO_2 content is found. Seasonal variations are about 1 part per million; monthly ones generally less. On the basis of

comparison against a reference gas from the Scripps Institute of Oceanography, the mean CO_2 concentration was found to be 323.9 ± 0.1 p.p.m.

Background studies, such as the seasonal interchange of CO_2 between mid latitude southern hemisphere oceans and the atmosphere resulting from temperature changes in the latter are continuing.

Boundary Layer CO_2

Since 1971, observations of CO_2 have been made at two ground sites (Aspendale and Rutherglen) and from a light aircraft up to an altitude of 3 km. Day to day variations in CO_2 content at any one site are no more than 2-3% of the atmospheric value, and are related to air trajectory. Space and time variations of near-surface CO_2 content are consistent with the land surface of the south eastern Australian continent acting as a surface sink, particularly during winter and spring.

Air of oceanic origin shows little variation with height, whereas air having a land track shows variations of up to 5 p.p.m. within the first 2 km.

Radioactivity

Observations from the surface air network from Port Moresby to Hobart continue, and measurements of radio-active isotopes from nuclear weapons tests and cosmis-ray sources are being analysed to study stratospheric-tropospheric interchange. Determination of the total β-content in monthly rainwater samples is also continuing.

Surface Ozone and Oxides of Nitrogen

Surface ozone measurements have continued at Darwin, Robertson (Sydney region), Aspendale and Macquarie Island, the latter site being equipped to provide continuous recording. At Aspendale a significant long term increase in ozone from the surface to 900 mbs indicates growing photochemical pollution. In this connection a new programme of

Studies of boundary layer carbon dioxide concentrations are made by collecting air samples using a light aircraft. Air is compressed into glass sample flasks using a self-contained drying and pumping unit. Analysis of the samples is completed at the Division's Aspendale Laboratory.

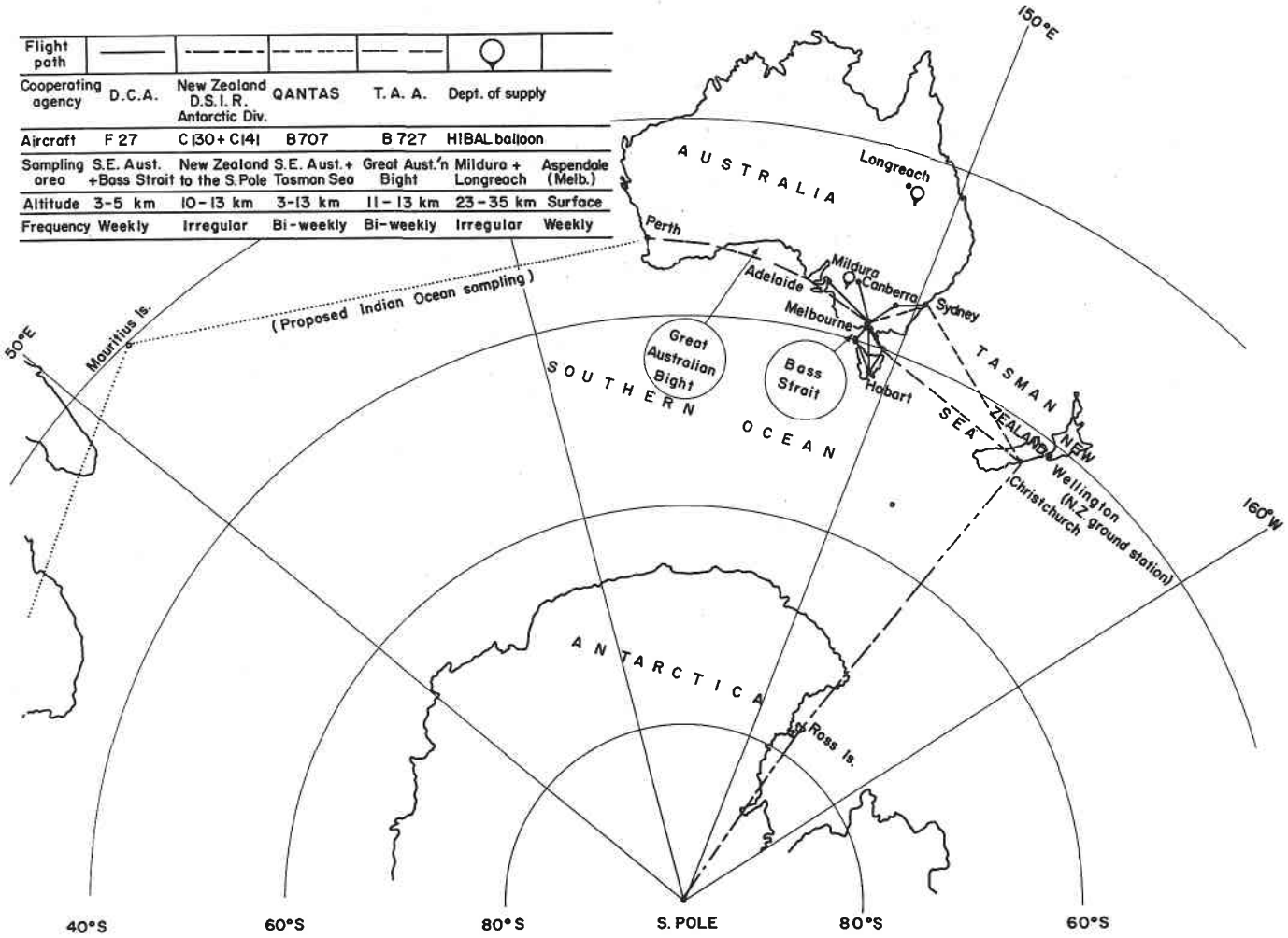

Figure 2. Details of the CO_2 sampling programme.

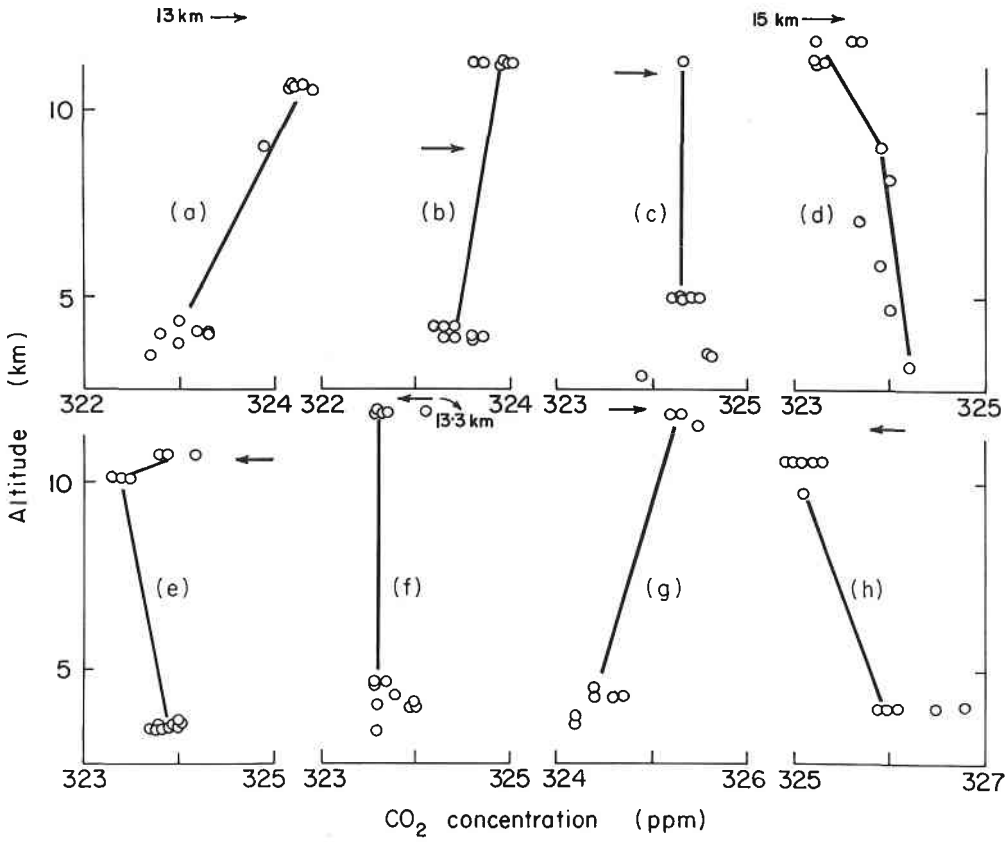

Figure 3. Examples of the variation of CO_2 concentration with height as a function of season. Each point represents an individual air sample analysis. The approximate level of the tropopause is indicated by the horizontal arrow. a, May 30, 1972; b, August 8, 1972; c, November 16, 1972; d, February 12, 1973; e, February 26, 1973; f, April 2, 1973; g, June 19, 1973; h, October 23, 1973.

measuring NO_x at ground level by spectrophotometer which measures absorbance, has been initiated.

Additional programmes for understanding the behaviour of ozone in the presence of the oxides of nitrogen and the study of NO_x itself in the free atmosphere are being planned.

The destruction rates of ozone over snow surfaces of various ages have been determined by profile-gradient techniques and, compared to rates over soil and vegetation, found to be much slower.

Carbon Monoxide

A hypothesis has been advanced within the Division that the observed carbon monoxide supersaturation in rainwater is the product of the photo decomposition of aldehydes in the rainwater by sunlight. A dynamical model of this Carbon Monoxide production has been constructed that successfully predicts the observed daytime supersaturation level.

Atmospheric Turbidity

The monitoring of atmospheric turbidity (a measure of pollution by aerosols) has continued and been intensified. The Division now has 5 years of records which are being analysed and related to specific weather situations. It is of interest that so far there has been no discernable long-term upward trend in turbidity as Melbourne (some 15 m to the NW) has grown. (The mean atmospheric turbidity over Aspendale is in fact less than the average minimum turbidity over the cleanest areas of the U.S.). A note of monitoring UV radiation can be found in section III.

VI UPPER ATMOSPHERE

Atmospheric ozone as a tracer in circulation studies of the upper atmosphere remained an important component of the Division's activities during 1972-73. A concentrated observational effort is

necessary for understanding the photo-chemical and dynamical aspects of the ozone layer, especially in view of the possible pollution of the stratosphere from nuclear testing and supersonic transport.

At the six stations comprising our network, observations of both total ozone and its vertical distribution by the umkehr method have continued. Routine weekly soundings using Mast-Brewer sensors have also continued at Aspendale. Improvements to the electronics of the Dobson instrument are being tested at Aspendale and a new spectrophotometer has been installed and recalibrated at the Macquarie Island site.

From the long series of direct sun observations made with Dobson spectrophotometers at Darwin, Brisbane, Aspendale and Macquarie Island, assessments in the character of atmospheric haze show that smaller size particles have increased in relation to larger size particles. Seasonal variations in haze character have been determined as well as the scattering effect of particles thrown up by the Bali volcanic eruption of 1963. Secular changes in the nature of the haze have led to a revision of the trend in total ozone and it has been estimated that about 53% of the apparent increase in total ozone between 1960 and 1970 could be ascribed to a changing haze situation.

The first eight years of soundings of the vertical distributions of ozone at Aspendale are being analysed for their climatological significance. Differences between mean annual cycles at Aspendale and Boulder (U.S.A.) are interpreted in terms of differences between circulations of the northern and southern hemispheres.

The long-term trends in ozone concentration at 36 standard levels show a significant increase in a shallow layer between the surface and about 900 mb level and above about 12 mb level, but a decreasing trend centred at about 40 mb. Increases at ground level indicate growing photo-chemical pollution at Aspendale and the opposing trends in the upper levels

probably indicate a slight decrease in the effective downward transport of ozone rich air from the region of photochemical activity.

Water Vapour

Because of the potential of water vapour as a tracer and its association with possible pollution of the stratosphere by supersonic aircraft, a reliable means of measuring the relatively small amounts of water vapour which exist at high levels has been sought. Recent aircraft flights up to about 15 km and balloon flights to 30 km indicate that our objective has been achieved. The instrument used for this purpose is essentially an infra-red hygrometer weighing about one kg and measuring the attenuation of the solar beam in the 6.3μ water vapour observation band. This work was undertaken with the support of the Department of Supply who operate Hi-Ball balloon ascents from Mildura (latitude 34°11'S, longitude 142°12'E) and made available the necessary payload and the RAAF who provided a Canberra aircraft.

Airglow

One means of coming to grips with the problem of the stratospheric circulation is via the mesosphere and the dynamic interaction between the two. By using the relatively straightforward technique of ground based air-glow measurements some indication of the relationship between 100 km transports and winds at lower levels can be obtained. Over the past two years, whenever the necessary cloud free conditions have existed, measurements are made of the intensity of the oxygen green line (I_g; $\lambda = 5577°\text{Å}$) using air-glow equipment located at Deniliquin, New South Wales. Tracking is automatic, north to south and east to west every 30 minutes. Year to year variations in I_g are consistent with rocket-sonde and rocket-grenade data in the northern hemisphere. For example in 1971 I_g was very much larger than in 1970 or 1972, corresponding to smaller ozone values in 1971 than in eight of the other two years.

VII AGRICULTURAL METEOROLOGY

The main concerns of the agricultural meteorology group has continued to be the exchange of heat, water vapour and carbon dioxide between the atmosphere and vegetated surfaces, particularly as related to crop water-loss and growth-rate.

The Rutherglen Wheat Investigations

During 1971 and 1972, in co-operation with the Victorian Department of Agriculture and Latrobe University, field experiments were carried out on successive crops of a winter wheat (Sherpa) at Rutherglen, northern Victoria. Some 60 meteorological and biological variables were monitored, many of them continuously. The venture was initiated principally to check certain aspects of a model of crop growth, but the data have also facilitated investigation of many facets of micro-meteorology and crop-growth.

Preliminary results confirm the validity of the energy-balance and extended combination approaches to evaporation estimation as described in earlier Annual Reports. Other calculations show that the turbulent transfer coefficient for total energy, i.e. sensible plus latent heat, was on average some 25% (and on occasion up to 55%) greater than the corresponding coefficient for momentum.

Together with carbon dioxide gradient data, momentum eddy transfer coefficients have been used to determine hourly mean CO_2 fluxes for more than 500 individual hours.

One interesting outcome of the work is an apparent strong dependence of crop photosynthesis on the nature of the incoming radiation. A given solar radiation flux density seems to produce widely differing rates of carbon dioxide uptake depending on the percentage diffuse radiation in the total incoming radiation. This is demonstrated in Fig. 2. The results suggest that the apparent light saturation observed in (a) is due to the diffuse

radiation being more effective in producing CO_2 uptake than direct radiation, and that, at higher total intensities, D/G tends to be smaller than at lower intensities.

Microclimate in Relation to Individual Leaves and Plants

Plant leaves in the field have been observed to exchange heat more readily than steady-flow theory would indicate. A study has been completed of convection from a flat-plate leaf model in a wind tunnel, with a sinusoidal variation in wind speed. Although horizontal plates were little affected at frequencies of 10 and 20 Hertz, mean heat transfer from tilted plates was up to 50% higher than in steady flows with the same mean speed. This enhancement is comparable to that observed in the field from real leaves.

A theoretical investigation of the adaptive significance of stomatal distribution on leaves is being refined. Net photo-synthesis rates of hypostomatous and amphistomatous leaves (with pores on one or both surfaces, respectively) are compared with stomatal resistance adjusted to provide for the same water loss in each case. Preliminary results indicate that the ratio of mesophyll transfer resistance to boundary-layer resistance determines which stomatal distribution gives a higher water use efficiency. It also appears that the results are sensitive to the form of the model used for representing the various photosynthetic resistances.

Combination Atmometer

This instrument consists of a pair of differently shaded but otherwise identical water containers. When exposed at some small height above a crop, their evaporation rates can combine in two ways, giving estimates of either incident net radiation or of crop potential evaporation. In an experiment at Aspendale, estimated and measured values for each of these variables were highly correlated ($r = 0.96$). A modified triple-container version of the instrument has been developed with a view to

obtaining estimates of actual evaporation. This has been tested at Rutherglen with encouraging initial results.

VIII COMMONWEALTH METEOROLOGY RESEARCH CENTRE

The Commonwealth Meteorology Research Centre in Melbourne is a joint venture between the Commonwealth Bureau of Meteorology and this Division. The objectives of the Centre are set out in previous annual reports. Its own annual report is published separately.

IX MISCELLANEOUS

The Division continues its work as an accredited laboratory of the National Association of Testing Authorities (NATA) in the fields of low speed anemometry, and atmospheric and terrestrial radiation. This Association exists to maintain various standards and for this purpose makes use of selected laboratories, both government and industrial. The total number of instruments received for calibration fluctuates from year to year, but typically is several hundred.

Forest Fires

We referred in last year's report to observations made on a fire near Darwin, N.T. which was lit for the Northern Territory Works Department so as to clear vegetation from the site of a new dam.

Analysis of these observations is now complete. Convection was observed to rise over the whole area of the fire (about 10,000 acres) to a height of about 3,000 m. Over a smaller area (about one tenth the total) a short lived tower of smoke rose to almost 6000 m. These features are related to the amount of fuel burnt, and the dilution of the heated air by ambient air.

X ACTIVITIES AND PERSONALIA

Retirements and Appointments

Dr. C.H.B. Priestley has retired as Chief of the Division and now devotes his whole time to Chairmanship of the Environmental Physics Research Laboratories. His place in the Division has been taken by Dr. G. B. Tucker.

December 1972 saw the retirement of Mr. E.L. Deacon - a member of the Division since its inception in 1947.

After 10 years with us Mr. B.B. Hicks resigned to take up an appointment with the Argonne National Laboratory in Illinois, U.S.A.

From the RAAF Academy, Dr. Ian Barton joined the Division's Radiation Group in December 1972.

Overseas Visitors and Visits

In March 1973 Dr. G.B. Tucker spent time overseas principally to attend a meeting of the Joint Organising Committee of GARP. At the same time the opportunity was taken to visit meteorological establishments in the United Kingdom.

In November 1972 Dr. A.J. Dyer left for the U.S.A. to attend the 2nd Conference on the Climatic Impact Assessment Program. On the way he briefly visited New Zealand and the Mauna Loa Atmospheric Monitoring Station in Hawaii. The following May, Dr. Dyer spent two weeks in Japan attending a meeting of the Steering Committee and a study conference associated with the coming Air Mass Transformation Experiment (AMTEX) in February 1974.

Sponsored by the WMO, Mr. M.S. Boulahya from Algeria recently completed a 10-month fellowship with the Division studying agrometeorological techniques.

Dr. G. W. Paltridge spent two weeks in the U.S.A. in May 1973 making preliminary arrangements for the Division's participation in GATE next year (1974).

At the invitation of the National Center for Atmospheric Research, Mr. Ian Galbally is spending 9 months in Boulder, Colorado; studying techniques for measuring low concentration gases in the atmosphere.

Co-operative Ventures

Dr. Peter Baines has given a series of lectures on dynamical oceanography and meteorology at Monash University.

XI PUBLICATIONS

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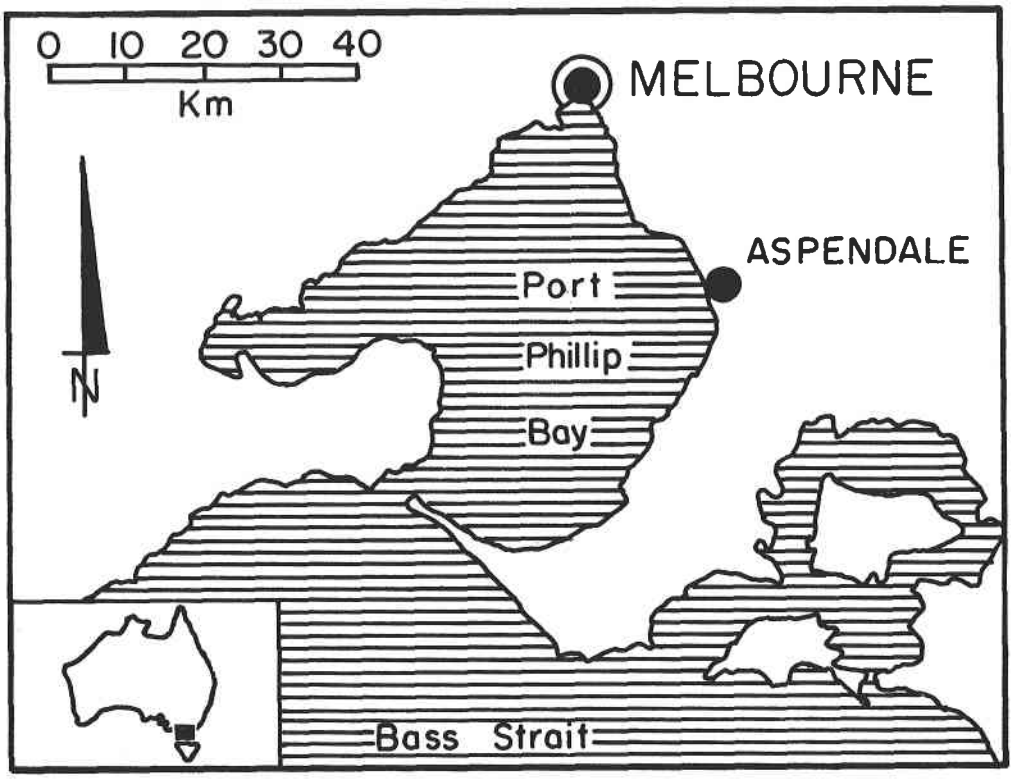
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