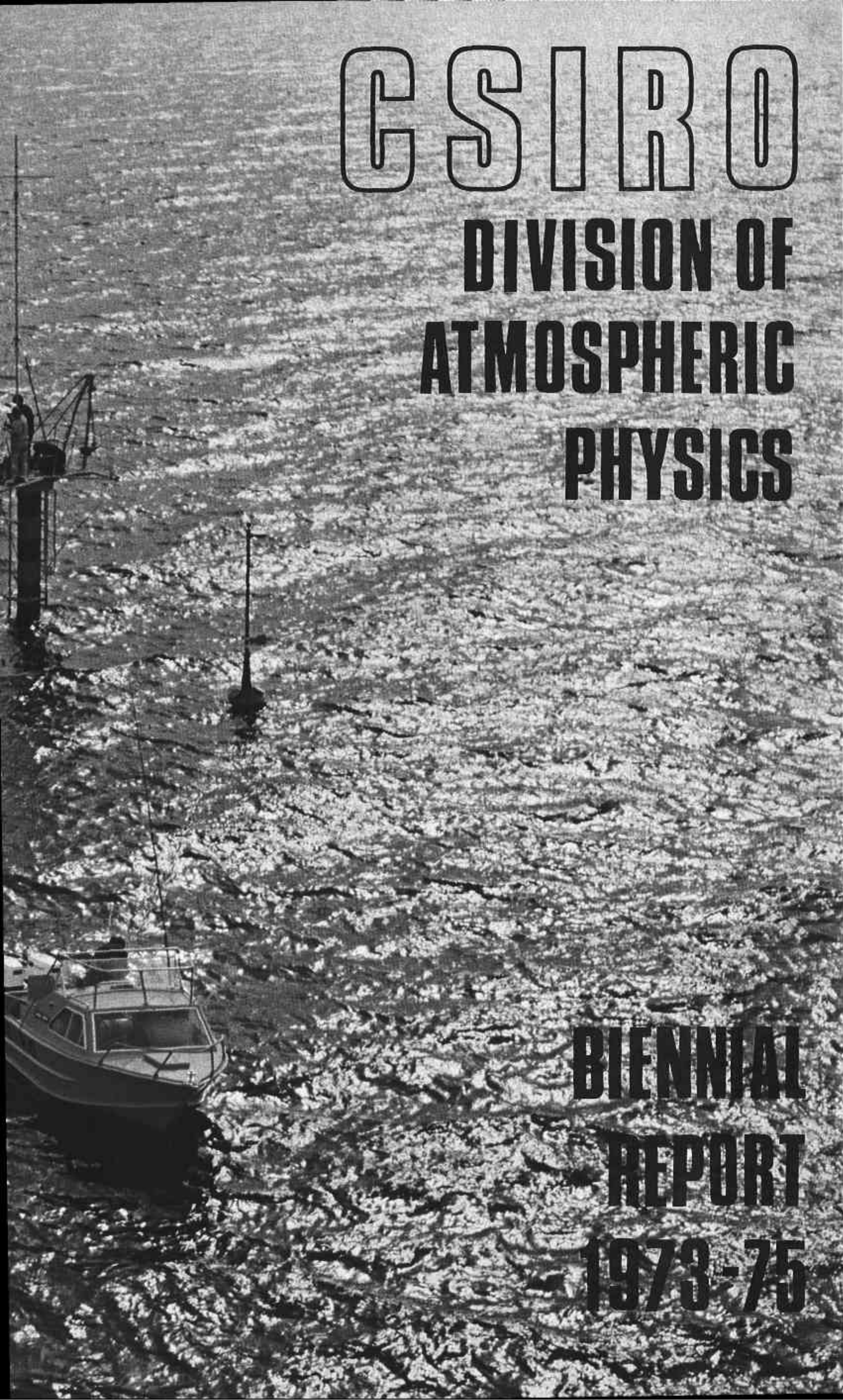


CSIRO

DIVISION OF ATMOSPHERIC PHYSICS

BIENNIAL REPORT 1973-75

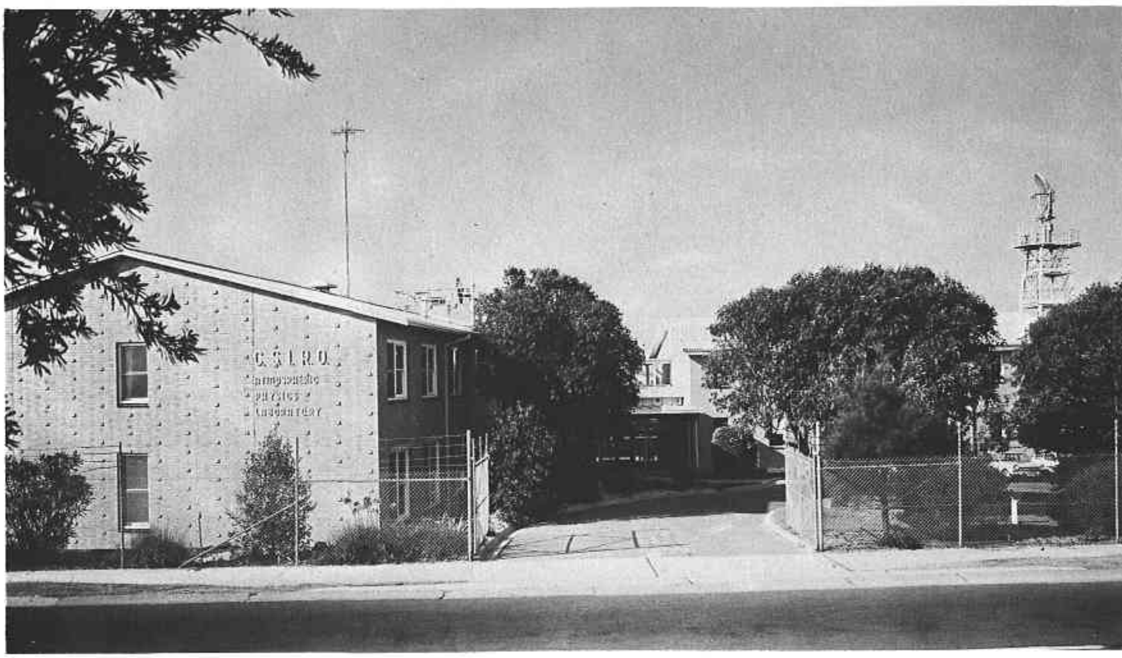
BIENNIAL REPORT 1973-75

Division of Atmospheric Physics

Commonwealth Scientific and Industrial

Research Organization, Australia

Melbourne



Division of Atmospheric Physics

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I. INTRODUCTION

A decision was made in 1974 to discontinue the practice of issuing annual reports, the longer term nature of many of the projects now undertaken being more suitable to a two-yearly review. This is the first such biennial report.

A feature of Divisional activities over the last two years has been the collaboration with other Divisions, University Departments, and with Federal and State Government agencies. A section of this report is devoted to briefly outlining these projects.

One of our most successful research programmes has been in the area of Geophysical Fluid Dynamics. Significant contributions have been made to the main aims of the Division: to gain a better understanding of the atmosphere and of the oceans as they affect the atmosphere. The influence of the work in this laboratory is being felt through most of the other areas of the Division.

The programme of research in atmospheric chemistry has also been of considerable significance. Unfortunately the expansion of effort in this area received a set-back with the untimely death of Dr. Bill Mansfield who had recently joined the Division and would have played a major part in an expanded programme.

A notable deficiency in atmospheric science is the lack of an adequate theory of climate. A re-orientation of some parts of the Division's resources and staff has enabled a new focus on problems of climate to be effected. In this programme, close collaboration with the Australian Numerical Meteorology Research Centre is of vital importance. Burgeoning activities include studies of the pattern of climate, analyses of relevant mechanisms and a consideration of appropriate climate models. A major stumbling block is likely to be inadequate knowledge of the behaviour of the oceans, particularly the surface mixed layer which interacts strongly with the atmosphere. While air-sea interaction activities within the Division will have relevance to this problem a serious gap exists in research in physical oceanography.

II. GEOPHYSICAL FLUID DYNAMICS

The aims of the geophysical fluid dynamics group are to further the understanding of dynamical processes in the atmosphere, and to a lesser extent in the oceans, principally by the use of theoretical studies and laboratory models. The basic philosophy is to study simple models of particular phenomena in isolation, and so build up knowledge of the complexity of atmospheric motions via a piece meal approach.

The group now has a well-equipped laboratory, which includes a number of tanks for internal wave and convection experiments, a rotating turntable, TV cameras and video tape recorder, and schlieren optical equipment.

The activities cover almost the whole spectrum of atmospheric motions, from small-scale breaking internal waves to the largest scale quasi-geostropic motions, although for the past two years the emphasis has been on motions of medium scale (10—100 km) in the atmosphere and oceans.

Internal Tides in the Ocean

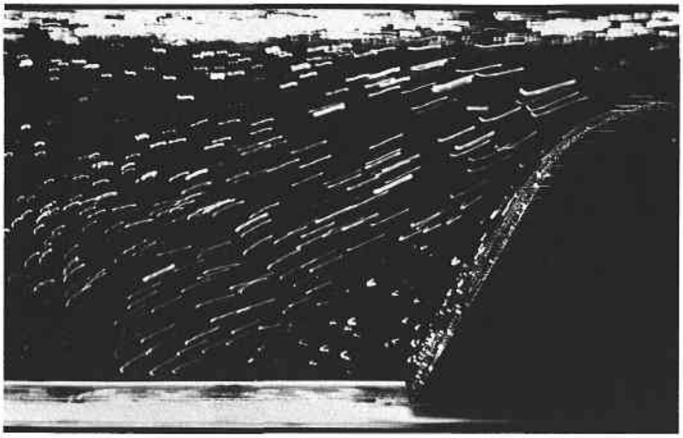
As mentioned in the last report (1972/73), internal tides (internal waves of tidal periods) are generated by surface tidal motion over bottom topography in the ocean, continental slopes being the most important features. The development of theoretical models for the prediction of internal tides has reached the stage where they may be applied to almost any continental slope, regardless of its shape, so that the associated tidal water movements and currents may be calculated. This may well have some practical application on the North-west shelf of Australia for example, where the motions are predominantly tidal and bottom currents are quite large. Figure 1 shows the vertical structure of the motion at two stages of the tidal cycle: flooding (1a) and high tide (1b).

The Stability of Planetary Waves and Atmospheric Predictability

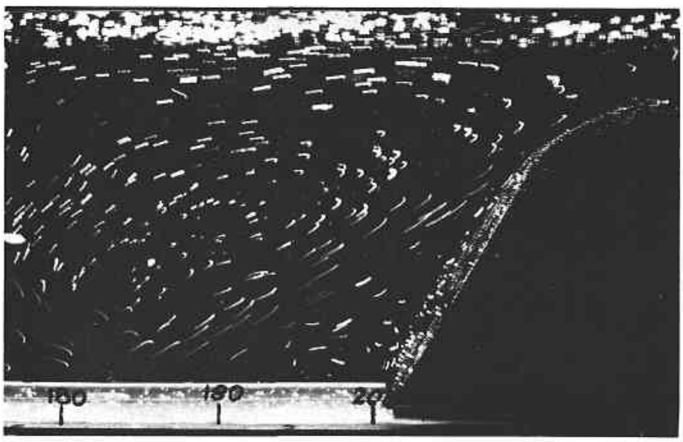
A study has been made of the stability of large-scale, quasi-geostrophic planetary waves, which constitute some of the ingredients of weather, using a barotropic non-divergent spherical model (i.e. one consisting of a single fluid layer of constant depth). It has been shown that, apart from waves of the very largest scale, all planetary waves are unstable if their amplitudes are large enough. Other planetary waves which may have very small amplitudes, so that they initially only appear as "noise", may grow to considerable magnitude at the expense of the initial wave. It appears that it is this phenomenon of the essential instability of the constituents of atmospheric motion which ultimately limits the period of time for which accurate weather forecasts may be made to about 2 to 3 weeks.

The Air Flow Over Mountains

A laboratory study of airflow over mountains has been made using model-mountains towed along the bottom of a tank filled with stratified salt water. A well-known feature of the flow field is the pattern of lee waves



1a



1b

Figure 1:
Two phases of internal tidal motion, generated by the surface tide over a continental slope (shown at the right) in a laboratory experiment viewed from one side. 1a at flooding; 1b at high tide. The fluid motion is made visible by photographic time exposure of the displacement of neutrally buoyant beads in a stratified fluid.

which occur downstream of the mountain, as shown in the accompanying figure. If these waves are sufficiently large, stagnant regions develop which are associated with the phenomenon of clear air turbulence. The initial aim of the study was to test observed criteria for the formation of rotors, with theoretical criteria, based on the common assumption that the mountain has no influence on the flow far upstream. The result was a complete lack of agreement between experiment and theory. This led to an examination of the flow upstream which revealed that, when the waves downstream were generated, the mountain always produced effects which, in ideal conditions, propagated infinitely far upstream. These effects are similar to the "shear fronts" mentioned in the previous report, and cause modifications to the airstream profile incident on the mountain. They throw new light on the nature of air flow over and around mountains, and theoretical and experimental studies are continuing. Figure 2 is a series of photographs taken during a laboratory experiment showing the development of a stagnant region from initiation at (1) to completion at (6).

Break-up of Ground Based Inversion

A laboratory model of the convective penetration of an atmospheric temperature inversion by ground heating has been studied. The experiments have shown that practically all the available energy released by ground heating goes into increasing the depth of the mixed region by convective stirring – there is little penetrative erosion of the inversion base. However, the convectively driven distortions of the inversion base generate considerable internal wave activity above it, as shown in Figure 3.

To determine the energy associated with the internal waves, a quantitative colour schlieren technique has been devised. This permits the resolution of refractive index gradients as small as 2×10^{-8}/m: in the laboratory tank this represents an ability to resolve amplitudes to within 0.3mm in wavelengths of 60mm.

Although not more than 1% of the available potential energy of convection is converted into internal waves, the latter can propagate far from the convective region, taking their energy with them. This amounts to a large flux of energy which may have important consequences at higher altitudes.

Laboratory Simulation of Stratus Cloud

Stratus cloud commonly radiates more heat from its upper surface than it receives from the sun, creating an unstable convection within the cloud. This convection causes additional cooling because dry air overlying the cloud is 'entrained' into it, resulting in the evaporation of some of the cloud's suspended liquid water.

The thermal budget of such clouds is thus partially dependent on the rate at which they entrain overlying air. To give a basis for the prediction of this entrainment a laboratory simulation was devised. An inverted model of a cloud was created in water by overlying cold slightly acidic water with warm slightly alkaline water. Instead of cooling from above, the model was heated from below by sodium lamps, the energy from which was absorbed in the upper portion of the cloud by the addition of thymol blue to that layer. This experiment provides some results of convection entrainment which have a different character from the more conventional laboratory studies where the source of convection is at a rigid boundary.

Angular Momentum Diffusion

A previous report described an experiment demonstrating the effect of fine scale turbulent mixing on a closed, uniformly rotating body of fluid. A new experiment has now been devised to simulate more closely and quantifiably the kind of convective mixing which occurs in the atmosphere, while excluding direct buoyancy effects. This was accomplished by driving a circulation of water through an array of closely-spaced holes in the bottom of a closed water-filled cylinder mounted on a rotating turntable. Intense cyclonic vortices signifying a diffusion of angular momentum, were observed (see Figure 4). The profiles of velocity in these vortices for a wide variety

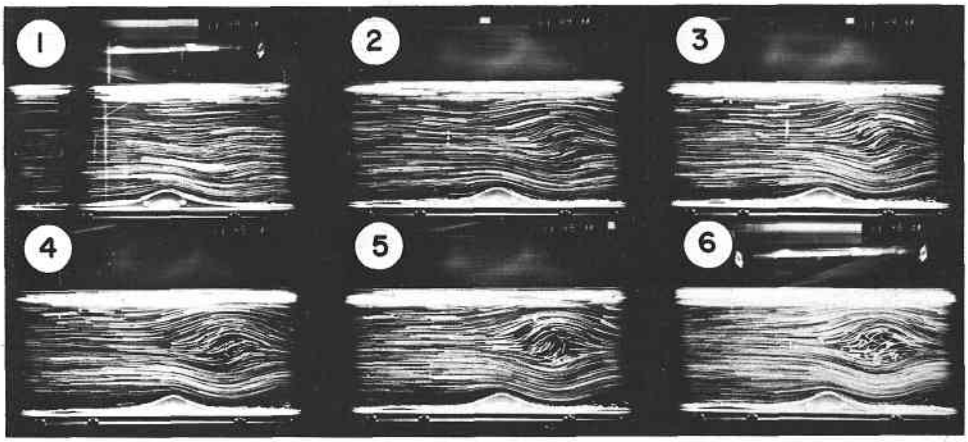


Figure 2: The development of lee waves in the flow (from left to right) of a density-stratified fluid over a mountain, showing the formation of a stagnant region.

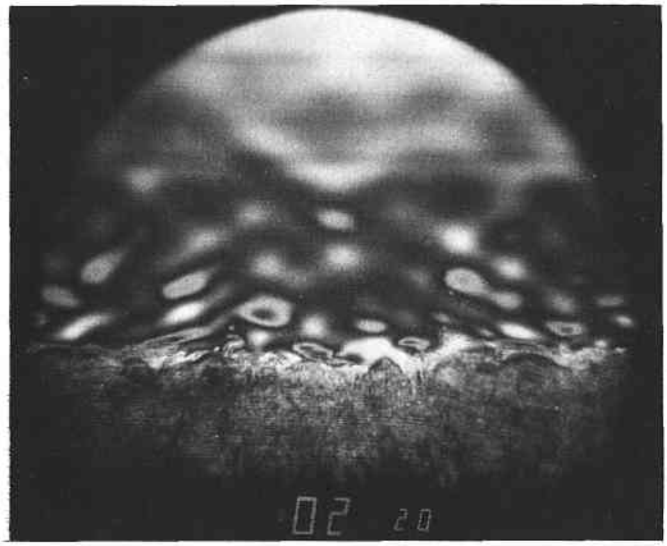


Figure 3:
Schlieren photograph (original in colour) of a laboratory experiment — showing a growing convecting region, (lower one third of picture) and the internal waves generated above it.

of experimental variables have now been analysed. These velocity profiles reveal a remarkable similarity which quantitatively confirms both in scaling and form an hypothesis which states that convective eddying in rotation diffuses angular momentum at a rate measured in terms of an angular momentum gradient, and a diffusivity which remains at a constant fraction of that for diffusion of relative velocity. This property is intrinsic to the convection, providing its Rossby number (defining the ratio of eddy vorticity to background vorticity) is below a critical value required for the eddies to be approximately two-dimensional.

This result promises to have widespread application, not only in the parameterizing and numerical modelling of atmospheric phenomena but in geophysics generally, because it suggests that the diffusivity of rotationally

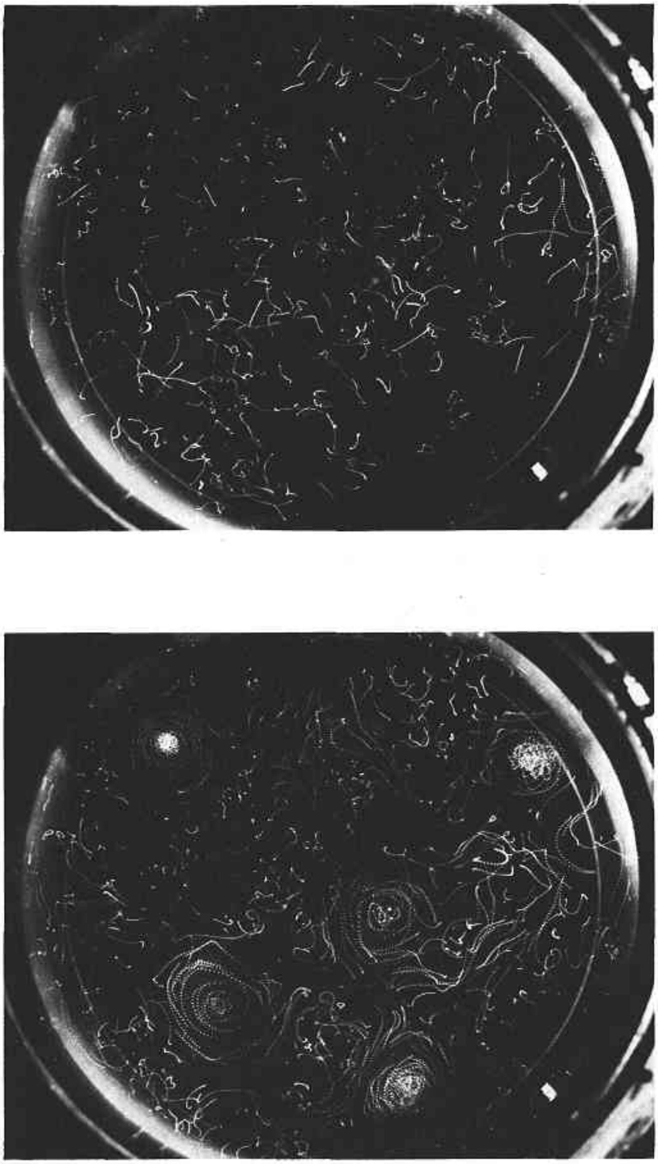


Figure 4:
An experiment illustrating angular momentum diffusion. Turbulence generated in a cylinder of water by an array of jets on the bottom is viewed from above. In the picture at top the cylinder is stationary, and in the picture at bottom it is rotating, with a consequent formation of cyclonic vortices from the turbulence.

modified eddies is characterized by a single horizontal velocity. Experiments at Woods Hole Oceanographic Institution* are now being conducted to explore the importance of Rossby wave radiation stress and potential vorticity diffusion (comparative to angular momentum diffusion) on the redistribution of mean velocity in rotating systems.

Parametric Instability and the Maintenance of Fine Scale Structure in Stratified Media

In a study reported previously it was demonstrated that a large scale internal wave field in a stable, continuously stratified medium, is capable of

*See Section VIII

exciting instability in fine scale waves whose frequency is nearly one half of that of the large scale wave.

One implication of this result was that in the atmosphere and the ocean, where waves of all scales are present simultaneously, the finer waves might be sustained by the intermittent passage of larger scale waves of nearly double frequency through them. An experiment at Woods Hole Oceanographic Institution has now been constructed to test this hypothesis and preliminary tests are providing positive confirmation of the theoretical predictions.

Future Prospects

Satellites, and large scale international observation experiments are providing an unprecedented wealth of detail on the structure of the large scale motions in the atmosphere and ocean. The deficiencies of theoretical and numerical models in describing this structure are revealed in similar detail. These deficiencies are to a major extent due to the inadequacy of 'parameterization' of those sub grid scale processes which determine the dynamics of the larger scale. It is in clarifying the physical basis for parameterization that geophysical fluid dynamics modelling will continue to play a useful part.

A good example is the experiment on rotation and convective mixing mentioned above. The extreme idealization of that experiment allowed the quantitative confirmation of a basic physical concept (the property of angular momentum diffusivity) but simple modifications introducing buoyancy are planned which will reveal more directly the relevance of the process to the initiation of tropical cyclones.

Another example is the failure of the accepted formulations for convective entrainment when applied to the stratus cloud simulation, also referred to earlier in this section. These formulations are used widely in numerical models. Clearly, further experimentation to explore the discrepancy in this and other configurations is justified.

Similar examples exist in almost every other facet of the group's activity. The intention is to continue to refine theoretical and experimental models for better simulation of reality while adhering to the principle that the physical processes involved are best revealed 'one phenomenon at a time'.

III. METEOROLOGICAL PHENOMENA

The main activities in this field have changed somewhat since the previous report (1972/73), increasing attention now being given to environmental studies. The emphasis is not so much on surveys of particular sites — though some have been undertaken — as on the development of techniques, procedures and models applicable under a wide range of conditions.

Environmental Studies

Recently commenced, a major, long term programme sets out to assess the impact on the (atmospheric) environment of a projected power station complex in the Loy Yang area of the Latrobe Valley, Victoria. Emission of polluting materials from stacks and relatively large quantities of water vapour from cooling towers could lead to undesirably high concentrations of contaminants unless the valley is sufficiently well ventilated. Although this work, carried out in collaboration with the State Electricity Commission of Victoria (S.E.C.) is of an 'applied nature', the opportunity is being taken to use the valley as an outdoor laboratory to study a number of fundamental processes.

To determine to what extent and under what conditions a 'closed circulation' develops in the valley, a study is being made of slope and drainage winds in the area. Tethered balloons, ground arrays and a modified radiosonde carry instrumentation to measure pressure, temperature, humidity and wind velocity. Vertical profiles of the latter three elements are being obtained from a series of daily soundings which commenced in April 1975 and will continue for 12 months.

Phosphorous smoke flares provide a visual indication of wind flow. Later, sulphur hexafluoride — which can be detected in concentrations as low as 1 in 10^{12} by volume — will be used as a tracer to investigate dispersion of industrial air-borne pollutants.

These experiments are being backed up by numerical models of atmospheric fluxes. Although the work has only recently commenced it is apparent that, at the outset anyway, there will be a dearth of synoptic information to provide for adequate initialisation. It is hoped that a scheme of 'dynamic initialisation' — in which the prediction model itself is used to produce consistent initial conditions — will overcome the problem. To be decided immediately is the choice of a suitable vertical coordinate system. This is made difficult by relatively severe variations in topography, and a need to achieve extremely high resolution to cope with early morning high stability situations.

Westernport Bay is a growing industrial area and the ensuing development poses the problem of where to locate storm water drain outlets so that the material they discharge causes minimal nuisance. At the request of the Westernport Bay Environmental Study, the Division undertook an investigation to relate the drift of surface material to prevailing winds.

Theoretical calculations were supplemented by observations of drift cards, located and fixed by shore-based theodolites. The results provided clear proof of the need to locate outfalls to the north of an area known as Sandy Point so that resort areas to the south would remain free of debris.

The 'Ringlelman Scale' is an accepted means of putting a quantitative value on visual smoke nuisance. The scale, developed overseas, is affected by the background illumination: an attempt (initially unsuccessful) to apply the method in the Melbourne area, led to an examination of the physical basis of the scale in terms of the Aspendale solar and sky radiation records. The result – applicable to the Melbourne area – is a scale with a diurnal and seasonal variation permitting it to be used for any source, in terms of the optical density of the latter. The study has illustrated the difference between methods employed in the licensing practices of the Victorian Environmental Protection Authority and the British standards on visual smoke emission.

Work has continued on improving methods of estimating the increase in fog due to the (relatively warm) discharge of cooling water from a power station into a nearby body of water. The last report referred to this in the context of Newport, an inner suburb of Melbourne. Testimony has been given to the Court of Appeal relating to the issue of a license by the Environmental Protection Authority to the S.E.C. to operate this same station.

The Boundary Layer

The diurnal course of wind and temperature variation in the boundary layer has been computed with a variety of turbulent mixing formulations suggested in the literature, and the results checked against those of the Wangara field experiment held in 1967. This showed that formulations which are made to depend on the turbulence intensity, with some allowance for "background turbulence", achieved the best simulation, but are expensive in computer time compared with one devised by the Division and which has performed satisfactorily.

Computation of the mean surface wind speed and direction over the oceans from the mean pressure distribution, with the use of similarity theory, as modified (from the Wangara data) to take account of horizontal temperature gradients, yielded results in quite good accord with such observations as are available. This exercise shows that similarity theory, with allowance for horizontal temperature gradient, provides a reasonable basis for relating surface stress, and hence surface wind, to the isobaric pattern.

In July-August, 1974, a successful field expedition (employing over 20 staff) was undertaken at Daly Waters, N.T. The purpose, to extend our knowledge of the boundary layer to tropical continental regions. Measurement of wind, temperature and humidity were made by mast- and balloon-borne sensors, and fluxes of heat and momentum near the earth's surface were measured, all of them continuously for 30 days. It is expected that these data, when finally evaluated, will provide a better basis for understanding near-surface processes, including the nocturnal low level ($\sim$ 200m) wind maximum of up to 20 m sec.$^{-1}$, at least in the tropical savannah lands.

The numerical studies of sea breezes referred to in earlier reports have continued. Their dependence on orography, cloudiness, ground roughness, pressure distribution, initial temperature structure and latitude has been checked against observations from a former field expedition to the Coorong-Renmark area of South Australia and a satisfactory correspondence achieved.

Lightning and Precipitation Rate

Very heavy precipitation, often capable of leading to flooding in some areas, is sometimes associated with a high frequency of lightning. It is possible that a useful relation can be obtained between this frequency, rate of precipitation over a catchment area, and hence downstream flooding. This may be particularly true in mountainous regions in relatively low latitudes. This relation, if confirmed, will be consistent with the most intense precipitation being formed in very strong, deep convective updraughts embedded in the storm cloud mass. It would also throw light on the unsolved problem of charge separation mechanism necessary to account for lightning.

To test the hypothesis, the critical voltage of a lightning flash detector was adjusted to detect discharges of moderate intensity within a radius of 10 km. With the cooperation of the Victorian State Rivers and Water Supply Commission, the instrument, together with a suitable recording device, has been located in the centre of the relatively circular Yackandandah catchment area in northern Victoria. A continuously recording water level stream gauge is located at the outlet to the catchment. During the first three months of operation only one relevant storm was sampled, but an encouraging association emerged. It is hoped that data from about 20 such occasions with a fair spread of intensity will be acquired over a period of two years.

Thermal Convection

This section deals with some of the results from the Hay expedition investigating thermal convection and referred to in our last (1972/73) Annual Report. The objective was to gain a better understanding of the natural convection process and, in particular, an elucidation of the manner in which small-scale eddies and plumes, which transfer heat into the lowest few metres of the atmosphere, give rise to the larger scale thermals which extend up to heights of some 1 or 2 km.

Winds and temperatures up to 32 m were measured from a mast whilst the pattern of surface air flow was recorded by an array of wind-speed/direction instruments set at a height of 1.5 m at 100 metre intervals across the wind direction. Thermals passing across the site were tracked by gliders, their position being monitored from the ground.

It was found that the thermals are fed continuously from right near the ground. They do not rise from individual small-scale plumes or coalescence of plumes, but are driven by the warm surface layer as a whole in the lowest ten or twenty metres above the ground. Their form is that of thin-walled cellular convection, usually polygonal – the cells being typically about 2 km across, and the walls roughly 100 m thick. Under the conditions of the experiment, the cellular structure extended only to limited heights – around 200 or 300 m. Above this there were isolated columnar thermals – the familiar "thermals" proper in which gliders climb.

Two results of this work are of immediate practical importance. The net heat flux carried by the cell walls approximates to 10% of the total flux at 5 m – implying a cell wall sampling error of only about 3% when carrying out heat flux measurements using the eddy correlation technique. The structure of the convection also explains the spurious, apparent negative shearing stress often met with when attempting to measure heat fluxes above 10 m.

Numerical Simulation of Cumulonimbus Cloud

A diabatic heating model of columnar updraught, originally developed to study the formation of tornados has been modified and applied to updraught in a cumulonimbus cloud. The model simulates realistically such features as a protected warm core and a dome-like top: it also specifies the conditions under which the cloud will penetrate the tropopause. Since the latter involves the injection of water vapour into the stratosphere, the results have implications for the general circulation. The success of the model lends support to two of its major postulates. Firstly that lateral transfer of heat and momentum by turbulence is more important than transfer on the scale of the cloud itself. Secondly that the net vertical force on a fluid element is defined as the buoyancy relative to adjacent cloud elements rather than the ambient air.

Layer Echoes and Storms

Observations from the Division's 10 cm radar at Aspendale together with others from the Bureau of Meteorology's radar in Brisbane, have been used to carry out further analyses of the extensive layer echoes which are found ahead of convective and frontal storms. The results confirmed earlier findings viz that these echoes are due to Rayleigh scattering from ice crystals originating in the top of cumulonimbus and anvil clouds. Further, calculations show that on average one to two million tonnes of ice are ejected from a major cell of a moderate/severe storm complex. This compares well with an independent estimate based on water substance continuity. Although conclusive in-situ measurements are still lacking there is indirect evidence that the concentration of ice particles having diameters between 100μ and 500μ is sufficient to account for their playing a part in the natural seeding of middle-level clouds. This work has been discontinued.

IV. CLIMATE AND THE GENERAL CIRCULATION

The physical basis of climate and climatic change involves many complicated processes taking place in both the atmosphere and the oceans. It is essential that the roles of both regions be incorporated realistically in any model. A considerable amount of work on some relevant problems has already been carried out by the Division, notably air/sea interaction, ozone and radiation (including the latter's inter-relation with clouds). However much further research is needed to properly understand and take into account the very important global transfer mechanisms which operate in the atmosphere and oceans, and to synthesise the diverse physical mechanisms which are the component parts of climate.

With the object of closing some of these gaps in our understanding, a small group has recently been formed to develop dynamical theory and model climate. This is currently engaged in studies of the patterns of climatic change and variability within the period of instrumental record, the underlying physical mechanisms — including large scale transports of momentum and heat — and aspects of simplified climatic modelling. This work complements the more complex numerical modelling of the general circulation being undertaken at the Australian Numerical Meteorology Research Centre.

Initially, climate change will be examined on a time scale from a season to one or two years: periods of these lengths have the most direct impact on man. Ultimately it is hoped to place more effort into studies which may hold out hope of predicting changes in climate over longer periods of time.

Pattern of Climatic Change in Australia

Earlier work has demonstrated the importance of the mean latitude of the subtropical high pressure belt, L, in relation to Australian rainfall and other climatic variables. It has now been shown that another major influence on Australian rainfall is the so-called 'Southern Oscillation' index, S, which was discussed in the 1964-65 and earlier reports. The index is a measure of the average east-west pressure difference between the semi-permanent eastern Pacific high and the low over the Indonesian region. A high index indicates increased flow of moist unstable tropical air over northern and eastern Australia leading to high rainfall in these areas. It has been shown that correlations of annual rainfall with S and with L together account for more than half of the total year to year variability in Australian rainfall.

On a longer time-scale, changes in rainfall over the period of instrumental record in Australia have been examined. Earlier work has pointed to the significant decrease in mean rainfall which occurred over much of eastern Australia in the 1890's. Current work shows that an increase in mean rainfall of some 10 to 30 per cent occurred over part of eastern Australia in the mid 1940's, although the latter change has not completely reversed the changes in the 1890's. The absolute change in the mid 1940's is shown in Figure 5: however the maximum percentage changes which amount to more than 20%, occur in inland N.S.W.

The pattern of change in mean rainfall which occurred in the 1940's appears to be related to that apparent in year to year variations associated with the Southern Oscillation index. This suggests that changes on a time scale of decades may be the product of the same underlying physical mechanisms which are responsible for shorter term variations in rainfall.

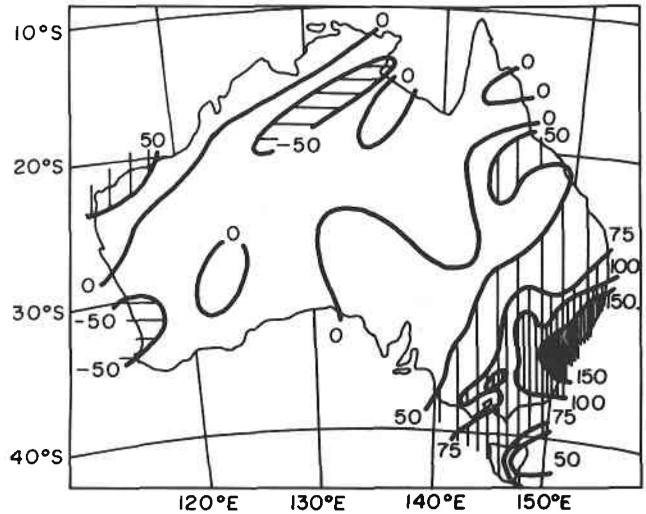


Figure 5:
Absolute change in mean annual rainfall, in mm, from the period 1913-1945 to the period 1946-1974. The large areas of increased rainfall in eastern Australia amount to increases of more than 20% in parts of inland N.S.W.

Large Scale Local Eddy Transports

A new examination of the large scale local eddy flux of heat has been carried out using detailed and frequent (3-hourly) upper air soundings over the period of one month, made several years ago at a site near Melbourne (The Laverton Serial Sounding Experiment). A relation is revealed between the eddy flux vector of heat and both the mean horizontal temperature gradient and the mean vector wind. This has a distinct vertical structure and suggests a three-tier subdivision of the atmosphere between the surface and the middle stratosphere. Subsequent computations using routine upper air data from Australia and a few selected stations in the Northern Hemisphere suggest that the relation may be sufficiently reliable to be used to represent eddy transports in climate models. Further work planned includes observational studies to confirm the generality of the relation and the construction of a very simple three-dimensional climate model which can be used to investigate the implications of the relation.

Numerical Climate Models

Work has been carried out on the development of a numerical climate model with a seasonal cycle and land-sea contrasts. Using this model a number of experiments have been performed aimed at elucidating the nature and inter-relation of the numerous feedback mechanisms. It is found, for example, that an increase in the carbon dioxide concentration (which could result from increased burning of fossil fuels) would cause the global mean temperature to rise, the temperature change being greatest in high latitudes in the winter months due to the strong albedo-temperature coupling. A reduction in the effective solar constant (due for example to an increase in atmospheric aerosol concentration) would cause the global mean temperature to fall, the largest temperature change again occurring in high latitudes. Studies have also been carried out on the sensitivity of the climate model to changes in numerous parameters including cloud cover, aerosol concentration, land and sea distribution and so on.

Analytical, as well as numerical studies of a number of different climate models are continuing with particular emphasis on the albedo-temperature feedback mechanism and the stability and multiple-branch nature of the solutions.

As a preliminary to deriving eddy flux parameterizations for use in statistical-dynamical climate models, an analysis is being made of unstable baroclinic waves on a rotating sphere.

Cloud-Climate Interaction

All general circulation models of global weather and climate include at least one of the major assumptions: i.e. either a fixed cloud amount and distribution and/or a fixed sea surface temperature. Both assumptions are equivalent in that they **'force'** the global energy balance (and hence the predicted climate) to the observed value. Methods of releasing this arbitrary constraint have been examined and it has been shown that the overall planetary system seems to have adopted a format such that the total entropy production rate is a minimum. It has yet to be proved that the planetary system **should** adopt such a format — as it can be proved for non-turbulent systems for instance. However, if one accepts that such an overall constraint is operative, then it is possible to use this constraint to design models which do not have arbitrarily fixed cloud and sea surface temperatures. It may then be possible to make a priori climate predictions (that is predictions which do not require assumptions about basic dependent variables). A zonal average model based on the constraint predicts surface temperatures and cloud amounts very similar to those of the real world.

V. ATMOSPHERIC CHEMISTRY

Carbon Dioxide

Since the appearance of the previous report (1972/73), measurements of the space and time variations of carbon dioxide in the troposphere and stratosphere have been accumulated. The continued support of the Air Transport Group (Department of Transport), Qantas and TAA has resulted in a comprehensive coverage of the Australian-New Zealand sector of the Southern Hemisphere.

(a) Instrumentation

In addition to the observational programme, during the past eighteen months, much effort has been directed towards the discovery and elucidation of errors existing in all previously published baseline CO_2 data. These errors are due to pressure broadening of the CO_2 absorption lines by nitrogen so that CO_2 concentrations as indicated by nondispersive infrared analysers depend on the relative ratios of oxygen, nitrogen and argon present in the instrument's reference and sample cells. The magnitude and sign of this carrier gas error depend on the make of analyser as well as on the ambient pressure so that despite the international exchange of standard calibration gases, inter-station differences due to the error exceed the actual concentration differences.

(b) Baseline monitoring and interpretation

Some of the monitoring data accumulated since the commencement of the CO_2 project are shown in Figure 6. Air samples collected over the Tasman Sea are of particular interest because they may originate either in the troposphere or stratosphere. Thus for each flight, tropopause levels have been estimated from radiosonde data (Australian east coast and New Zealand stations) and the data classified according to the probable origin of the sample.

A notable feature was the pronounced 1974 Autumn minimum in CO_2 concentrations. The seasonal variation appears to be greatest in the upper troposphere and least in the stratosphere and suggests a net north-south interhemispheric exchange of upper tropospheric air.

The increase in annual mean concentration based on the limited number of years of data available appears to be slightly less than 1 ppmv yr^{-1}.

(c) Carbon isotope studies

It is established that over the past decade and a half the atmospheric CO_2 concentration has been increased. Estimates of trends earlier this century are based on data collected for other purposes using inferior techniques. We have initiated two studies which have as their primary aims, a determination of the CO_2 content of the atmosphere in past centuries and millenia and a better understanding of the mechanisms which determine the level of CO_2 concentration.

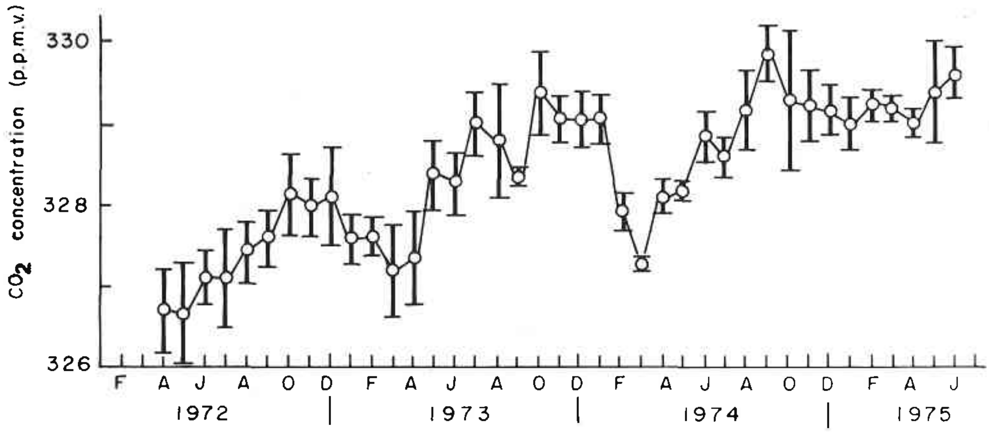


Figure 6: Mean monthly data collected from a Fokker Friendship (F27) and Piper Commanche (PA30). Data (expressed in the 1974 Manometric Scale) for altitudes between 3.5 and 5 km. Vertical bars represent standard deviations of data about each mean.

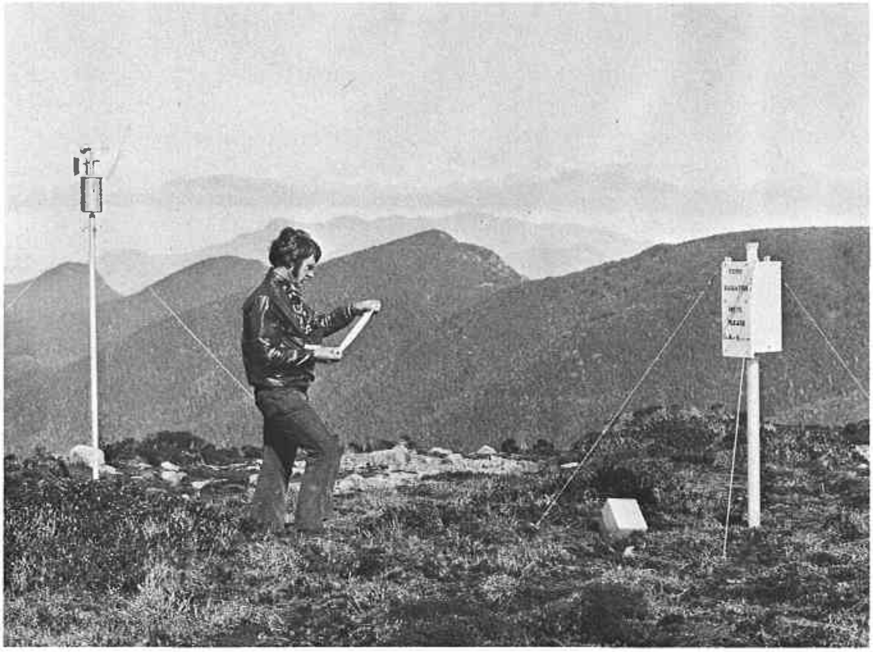


Figure 7: One of a number of possible sites now under investigation for a future atmospheric baseline monitoring station.

The first of these is a study of the stable isotope ratios in the growth rings of trees. C^{14}/C^{12} ratios in carbon containing compounds have been used in radiocarbon dating (relying on the steady radioactive decay of the C^{14}). Comparison with other dating methods (e.g. dendrochronology) shows deviations in the radiocarbon dates, with secular and perhaps local effects. These variations have been attributed to variations in isotope fractionation in the growing wood and corrections applied have been derived from measurements of variations in the stable isotope ratio C^{13}/C^{12}.

The causes and magnitudes of fractionation effects are not well understood: possible influences are temperature or ambient CO_2 concentrations at the time of growth. Most authors acknowledge an additional effect in both C^{14}/C^{12} and C^{13}/C^{12} ratios due to the recent injection into the atmosphere of fossil fuel CO_2 (Seuss effect). However, there is some doubt that either fractionation effects or the Seuss effect can explain the 20th Century C^{13}/C^{12} trends as observed in some Northern Hemisphere trees.

Using trees and climatological data from Tasmania and South Australia our objective is to establish if these trends can be observed in the Southern Hemisphere (are they global changes?) and to relate variations in C^{13}/C^{12} ratios to historical changes in temperature or atmospheric composition.

(d) **Ice Cores and Ancient Atmospheres**

There have been a number of attempts to find well preserved ancient air entrapped in bubbles of polar ice. The results however are inconclusive particularly with respect to CO_2.

The second study of past atmospheric composition involves ice cores collected by the Australian National Antarctic Research Expedition. The ANARE cores are superior to those measured in some of the previous studies; for example, they have not been stored in dry ice, are from areas where melting and refreezing is unlikely to have occurred, have been tentatively dated, and comprise a wide spatial sample of deep cores — some dating back in excess of 10,000 years.

A mass spectrometer is being employed to measure the relative amounts of N_2^{28}, N_2^{29}, O_2^{32}, Ar^{40}, $C^{12}O_2^{16}$, plus the total gas trapped. It is hoped to gather information on the physical processes affecting the trapping and storage of the air and on the composition of past atmospheres.

Ozone

Ozone studies in this Division began with the principal objects of using ozone as a tracer to indicate atmospheric circulation and its role in the overall transfer of solar energy. Recently, however, a knowledge of ozone has assumed an importance in its own right, as a result of the possibility of exhaust gases from supersonic aircraft, aerosol sprays etc. affecting the stratospheric ozone layer. Therefore it is even more important to continue building up a well-documented climatology of the vertical distribution of ozone as a function of season, latitude and longitude.

In the Australian region, the observational programmes at Brisbane, Aspendale, Hobart, Perth and Macquarie Island have continued. Observations at Darwin were discontinued after the cyclone disaster of Christmas 1974 and the spectrophotometer returned to Aspendale for recalibration. It will be returned to Queensland shortly to be set up at a new site in Cairns.

Routine fortnightly ascents using Mast-Brewer sondes have continued at Aspendale, Victoria.

Trend analyses of total ozone and of ozone at various levels, have continued. Over the years 1963/1974, ozone has been decreasing at Aspendale but if the period selected is 1960/1970 an increase is observed. Clearly a wave type fluctuation more aptly describes the results. From a study of 100 mb temperature trends for the corresponding years, this fluctuation can be explained on the basis of circulation changes in the stratosphere. Analyses of unkehr observations and of ozone sonde data support the view.

Much effort has been put into detecting natural and possible man-induced trends in the global ozone content, yet to date, no adequate attempt has been made to assess the suitability of the global ozone monitoring network for this purpose. Such an examination has recently been carried out and has shown that, even allowing an ideal distribution of monitoring stations within the network, a real trend of 2½% per decade in total ozone, would require approximately 10 years of observations to establish, with 99% certainty, that such a trend existed. These difficulties stem from the high variability of the ozone amount above any particular station, which in turn is due to short-term variations in the weather and the seasonal cycle. These results have important implications relating to both the present distribution of ozone observing stations and the interpretation of the data, from the present far-from-ideal network.

There is no doubt that ozone plays a central part in the photochemistry of the atmosphere and it is important, therefore, to study the distribution of trace substances which may affect the behaviour of ozone. NO_2 is one of them. A method has been developed of measuring NO_2 using the Dobson spectrophotometer. It makes use of the absorption of NO_2 at wavelengths $\lambda 4377$ and $\lambda 4448$ and calls for only a slight modification to the instrument. Although the accuracy of the observation is not great, it is believed to be sufficient to provide an average background value of NO_2 against which any future changes in NO_2 may be assessed.

To date about one year's data of NO_2 at Aspendale gives an interesting seasonal variation of the gas very similar to that of ozone.

With the assistance of the Bureau of Meteorology, Antarctic Division of the Department of Science and the CSIRO Division of Cloud Physics, measurements of ozone in the surface air continue at Darwin, Robertson (NSW), Aspendale and Macquarie Island. The measurements are made with a continuous Brewer coulometric potassium iodide ozone detector. A gas phase chemiluminescent ozone detector has also recently been installed at

Aspendale. Extensive checks between the two methods show them to be comparable although the wet chemical method gives systematically lower concentrations. Surface ozone observations are being continued as part of global measurements of clean or background air.

Oxides of Nitrogen and Ammonia

Two years of measurements of NO_2 at ground level at Aspendale show an average daytime concentration of 1.3 pphm NO_2. Simultaneous measurements indicate that the NO_x concentration is about 1.5 times the NO_2 concentration during daytime at Aspendale. Observations at Mt. Buller and Cape Otway in background air gave maximum concentrations of NO_x of 0.1 and 0.5 pphm respectively. The concentration of ammonia in the background air is observed to be 0.1 pphm at sea level and negligible concentrations at higher altitudes. These measurements of NO_2 and ammonia in background air are the first measurements in the Southern Hemisphere.

A theoretical study has revealed that the natural emissions of oxides of nitrogen (odd nitrogen) and ammonia from the earth's surface in the Northern Hemisphere have upper limits of 3×10^3 g (N) yr^{-1} and 13×10^{13} g (N) $year^{-1}$ based on considerations of boundary layer resistance. The estimate indicates that man-made emissions are a major component of the nitrate cycle in the Northern Hemisphere.

Halocarbons

Chlorofluoromethanes, principally freon 11 ($CFCl_3$) and freon 12 (CF_2Cl_2) are being produced in large and increasing amounts as aerosol propellants and refrigerants. These compounds have been considered valuable as tracers of atmospheric motions because they are relatively inert in the troposphere.

Approximately 98% of the annual production of freon 11 is released in the Northern Hemisphere. Thus it is a useful tracer for identifying interhemispheric atmospheric transport. Concurrent measurement of CO_2 and freon 11 in tropospheric air samples should assist in the interpretation of the seasonal variations in the concentration of CO_2 observed in the Southern Hemisphere.

Recently there has been growing concern that the freons together with carbon tetrachloride ($CC1_4$) might contribute, via photo-dissociation, to the chlorine atom content in the stratosphere. It has been postulated that the latter can catalytically destroy ozone (O_3).

Just started, is an investigation into the ultimate fate of man-made carbon-tetrachloride released into the atmosphere. The sinks for this chemical in the environment — in decreasing order of importance — are photolysis in the stratosphere, hydrolysis in the ocean, gas phase reaction and uptake by land. It would appear that the current levels of carbon tetrachloride in the atmosphere can be explained entirely on the basis of man's activities and the injection of this material into the atmosphere.

The measurement has commenced of space and time variations of CCl_4 and $CFCl_3$ in the Southern Hemisphere, utilizing air samples collected for the CO_2 programme.

Stratospheric water vapour

A balloon-borne infrared radiometer has been used for the measurement of stratospheric water vapour at altitudes of 24 to 27 km. Radiance from two zenith angles, 70° and 45°, and from 12° below the horizon is monitored and from these data the amount of water vapour above the instrument is calculated. These measurements began in November 1972 and have continued at approximately bi-monthly intervals. The programme was interrupted last year as a result of some administrative changes affecting the Hibal balloon launching facility. However, the programme is continuing in collaboration with the CSIRO Division of Cloud Physics, using smaller balloons.

During July 1974 two comparison flights took place at Laramie, Wyoming, USA, where the radiometer data were compared with those from an aluminium oxide sensor. The results of the comparison have been published in an internal report of the University of Wyoming (see references).

A new version of the instrument with increased optical gain, has been developed. Flight trials to evaluate the new instrument and compare the data from both the new and old instruments are in progress.

Surface Air Sampling Network

(a) **Radioactivity**

Although influenced by atomic debris from nuclear weapons testing in the south Pacific region, data obtained from the surface air sampling network at several latitudes (9°S to 43°S) indicate that the summer peak in Be-7 concentrations propagates poleward at a rate of about 35 $cm.s^{-1}$. There is evidence of a spring peak preceding the summer maximum.

A low latitude injection of Be-7 during spring is apparent, and there is some evidence in the Cs-137/Be-7 isotope ratio data for a similar incursion at higher latitudes.

(b) **Atmospheric particulates**

Measurements of total particulate concentrations are obtained from the surface air sampling network at six locations in the environs of major cities along the eastern Australian coast and extending into Papua and New Guinea. During the first three years of operation of the network, concentrations average between 40 and 55 $\mu g/m^3$ for mainland Australia, with Hobart and Port Moresby yielding lower values.

Particulate concentrations obtained at neighbouring stations (for example, Melbourne and Sydney) tend to be positively correlated. Negative correlations are sometimes found between extreme southern and northern stations (for example, Melbourne and Townsville). These results are consistent with the relevance of wind direction in determining particulate levels.

VI. AIR-SURFACE INTERACTION

For many years the Division has put considerable effort into advancing our understanding of physical processes responsible for the interchange of energy (heat, water vapour and momentum) between the atmosphere and the underlying land surface. Observational techniques for use in a constant flux situation (low height and uniform surfaces) have paralleled developments in theory and we are now at the stage of extending operations to heterogeneous land areas and to the sea. Work over the land is likely to lead to an increasing emphasis on problems of meso-scale dimensions (heights up to 1 km and distances of tens of kilometres); whilst over the sea further endeavours will be needed, particularly in view of the difficult environmental conditions in which sensors, deployed in the open ocean, will have to operate.

To strengthen the team, resources are being redeployed from agrometeorology.

Air-Sea Interaction

The exchange of energy or matter between the lower atmosphere and the Earth's surface can be measured at a single location using turbulence sensors mounted within 10-20 m of the surface on an instrument tower. The vertical fluxes of momentum, heat and water vapour so measured are then related to the physical and aerodynamic features of the underlying surface (on a scale of kms) and to values of such basic quantities as wind speed, air and surface temperature (and humidity), net radiation, etc.

Measurements of the turbulent fluxes must be made over a number of different surfaces encompassing smooth and rough terrain (land) and the ocean, in a variety of weather conditions. Reliable flux representation on a scale of hundreds of km (typical of the grid scale used in numerical models of the atmosphere) then becomes feasible, based on an observational network of basic parameters such as indicated above and reliable 'maps' of surface aerodynamic roughness (see later in this section).

In practice, direct observations of the fluxes over the sea, particularly in a severe marine environment, depend upon suitable sensor, data logging and platform design. A prototype instrumented spar buoy was deployed in the Great Australian Bight from the Russian research vessel "Dimitri Mendelaev", giving valuable experience in deployment technique and performance of sensors under field conditions. Work on the buoy has continued (see cover photograph), with testing confined to Port Phillip Bay, anticipating a start soon on the transmission of data to the N.A.S.A. Nimbus-F Satellite.

Two expeditions to the Ryuku Islands in the East China Sea were made in relation to the G.A.R.P. Air Mass Transformation Experiment, (AMTEX, February, 1974 and 1975). The results of the first period have been analysed, and generally showed the 'neutral' drag coefficient (C_D)

increasing with wind speed, in contrast to the near-constancy of the 'neutral' heat transfer coefficient (C_H). The result is consistent with a review study showing that C_D/C_H depends on the roughness Reynolds number (Re), generally increasing as Re increases and being greatest over land. Exceptionally large air-sea temperature differences occurred in both AMTEX observation periods (the sea being warmer than the air by as much as 10°C). For one particular 5 day period, observed outgoing energy (in the form of sensible and latent heat) exceeded the available energy from net incoming radiation by more than an order of magnitude (660 wm^{-2} compared to 30 wm^{-2})! The computed Bowen ratio (sensible to latent heat flux) of 0.20 was consistent with the surface temperature of 21°C, and supported the results of earlier work in the Division. In the second AMTEX observational period, close examination of instantaneous flux values and high frequency spectral energy, indicated intermittent energy transfer occurring in bursts lasting several seconds, separated by non-active periods lasting for a minute or more. Thus the concept of 'average flux', and its implication in bulk transfer relations, requires further investigation, particularly in the highly unstable conditions experienced during AMTEX.

For use in field expeditions (such as AMTEX) a portable data recording system using cassette magnetic tapes has been constructed and successfully tested. It greatly facilitates data acquisition and on-site analysis.

Further refinement of the infra-red hygrometer referred to in the last annual report has been made, allowing for reliable eddy flux determination of evaporation.

Analyses of turbulent flux data obtained during three field expeditions (East China Sea, February 1975, Daly Waters, N.T., July 1974 (rough terrain) and Moree, N.S.W., April 1975 (short grass) will continue. Measurement of energy exchange over the ocean, particularly during the passage of cold fronts and squalls, will be made from the tower facility and the spar buoy in Port Phillip Bay, the buoy destined eventually for deployment in the Bight.

In addition, the computation and mapping of surface aerodynamic roughness will be undertaken, using a 2.5° square grid covering the Australian continent and surrounding ocean.

Air-Land Interaction

Over the past year Divisional activities in agrometeorology have been decreased. The cable pivot lysimeter, designed for easy installation in the field has undergone its final test; data from the Rutherglen Wheat Experiment has been worked up, as also has data from the former Potato and Pasture Water-Use studies at Aspendale. One of the points to emerge from the Rutherglen data analysis has been the good agreement between independently derived values of the turbulent transfer coefficients on the one hand from wind and temperature gradients above the wheat, and on the other from measured fluxes of heat and water vapour and the corresponding gradients of temperature and humidity.

Still uncompleted but nearing its end is the work on snow field hydrology in the Falls Creek area of the Victorian Alps. The object of this experiment is to develop a means of estimating snow melt rate and evaporation from simple micrometeorological observations.

The Daly Waters expedition has been mentioned earlier in this report: to study vertical fluxes in the lowest layers of the atmosphere, recordings of wind speed, temperature, humidity and various radiation and allied quantities were made continuously for about a month. Observations were made at several heights up to 48 m at each of three sites. Reduction of the data is still proceeding.

Towards the end of 1974 and early in 1975 a similar but less comprehensive set of profile measurments were made for the Westernport Bay Environmental Study. There was concern that increasing industrialization in the area might give rise to unacceptable levels of atmospheric pollution, and the work sought to assess the frequency of occurrence of temperature inversions and their role in controlling the dispersal of pollutants in the lower atmosphere. A 48 m mast was instrumented and local staff of the Environmental Study were trained to operate the sensors and automatic recording equipment.

The Division has long made use of portable masts on which to mount instruments during field expeditions – but in terms of ease of erection, ready access to instruments and low weight, none has proved ideal. Work has started on the design of a portable mast which embodies a pantograph principle, thus permitting instruments to be raised and lowered at will, yet permitting their verticality to be retained.

Bulk relationships for air/surface transfer

The *bulk aerodynamic* ("bulk") relationship for the lower atmosphere expresses the vertical flux of heat or water vapour simply in terms of mean wind speed and surface-to-air differences of temperature and specific humidity. This approach is particularly applicable over water surfaces, where the surface values are readily obtainable from the water temperature. Especially is it of considerable practical importance when evaluating the surface inputs to the atmosphere from the ocean, in assessing the evaporative losses from reservoirs and (via the "combination formula") from land surfaces.

Recently three modifications have been made to the basic formulation of the bulk relationship, enabling it to be more reliably applied in a wide range of conditions over different surfaces.

The first takes account of the effect of the thin molecular-transfer sublayer, in the air adjacent to the surface when the latter is reasonably smooth, as in the case of calm water. The second makes an adjustment for thermal stratification of the atmosphere ("diabatic" effect), and the third covers the extreme case of free convection i.e. an unstable situation when there is virtually no mean wind.

VII. RADIATION: SOLAR AND THERMAL

Current research follows two main lines; i) the interaction of clouds with solar and terrestrial radiation, particularly in the context of atmospheric radiation balance and ii) the use of radiation as a remote sensor for monitoring purposes.

In the case of the former a specific objective is the parameterisation of radiation quantities in a form suitable for inclusion in general circulation models. In respect of the latter, examples are: the assessment of surface characteristics such as moisture and sea roughness; the measurement of atmospheric turbity (resulting from suspended aerosols and pollutants); and the connection between ultraviolet depletion of incoming solar radiation and the quantity and nature of airborne material.

Lidar and High Cloud

In May of this year the Division took delivery of a laser radar (LIDAR), effectively a radar operating at a wavelength of 6943 Å. It transmits pulses of energy, having a peak power of tens of megawatts, and detects the signal returned from dust layers and clouds. Analysis of the return signal allows calculation of the heights and thickness of the relevant layer, together with information on the reflection and transmission of the layer to visible solar radiation (see Figure 8). This short wave information is obtained simultaneously with infrared-wavelength information gathered by the infrared radiometer developed by the Division and referred to in earlier reports.

Clouds reflect solar radiation back to space but reduce the infrared output from the earth. These two effects act in the opposite direction on the global energy balance, and the basic question is 'which effect dominates?' It is hoped to answer this and other similar questions for the various cloud types by using the radiometer-Lidar combination.

Microwave Remote Sensing

A central requirement for both agriculture and meteorology is a knowledge of the amount of water in the surface layers of the soil. The earth's surface emits radiation at microwave frequencies at a rate which is

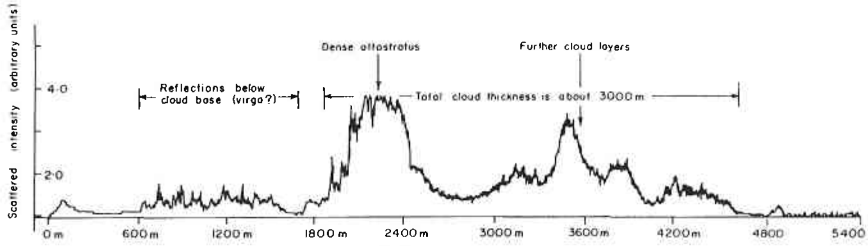


Figure 8: Return signal from different levels in the atmosphere when illuminated by a ruby laser pulse. Enhancements in signal at certain altitudes signify the presence of clouds or haze. Resolution in the vertical is 6 metres and the figure represents data which has been digitized and reproduced from magnetic tape.

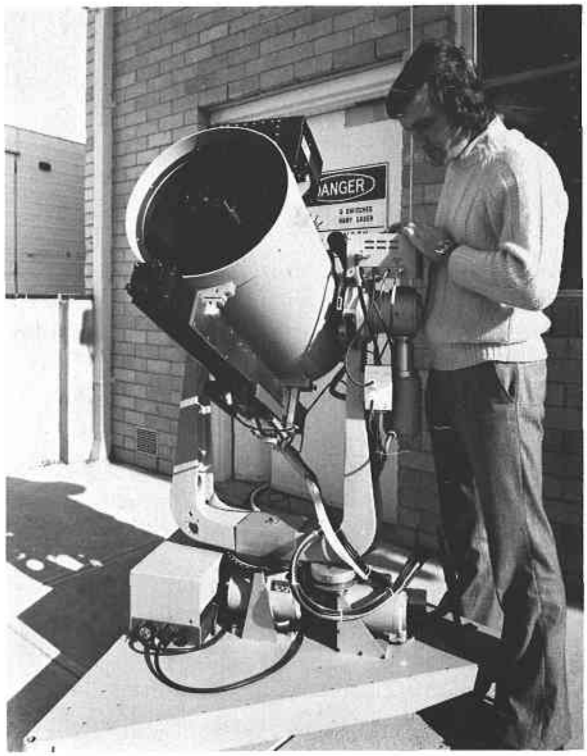


Figure 9:
The Division's
new Lidar System.

dependent (among other things) on the emissivity of the soil. This emissivity in turn depends on water content. To detect this type of radiation, a semi-portable microwave-radiometer has recently been built. Currently undergoing laboratory testing, it is designed for installation in an aircraft, enabling the instrument to look downwards at the earth. Initial flight trials are scheduled in conjunction with the Division of Chemical Physics. That Division is interested in monitoring the 'dampness' of forests and their potential for forest fires.

U.V. Radiation

The Division has developed and installed equipment to measure continuously the incoming solar ultra-violet radiation at a number of sites at different latitudes (Port Moresby, Townsville, Brisbane and Melbourne). The equipment has now been operating for six months and is intended to monitor U.V. for several decades as a check on any long-term variation arising from climate change. The network will, among other things, complement a similar network being installed at various base-line stations by the U.S.A.

Solar Energy Input to Australia

Based on experimental measurements of the reflectance of the various cloud types, use has been made of observed cloud amounts at 45 stations over Australia to calculate contour maps of solar energy availability over the

Continent. Comparison with observation at 9 stations shows that the difference between calculated and observed monthly average inputs is never greater than 10 per cent and is usually within 5 per cent. Bearing in mind the typical measurement inaccuracy of 5 per cent, the agreement is very good. Thus for most general requirements, it seems likely that **extensive** solar monitoring networks will not be necessary.

The calculations include information on direct and diffuse radiation fluxes, as well as the total solar input to inclined planes. Computations have been further extended to produce contour maps of the seasonal average net radiation input (i.e. both solar and infrared radiation).

U.V. Absorption by Sea Water

UV absorption by sea water is a useful index of water quality and is a means of detecting organic or inorganic matter in water. A method has been developed of using a Dobson spectrophotometer for this purpose. Measurements on samples collected in Port Phillip Bay showed up the varying degrees of water pollution due to dissolved organic matter at Bayside beaches. As can be seen from Figure 10, the degree of pollution increased markedly in the vicinity of outfalls from land drainage systems.

An examination of Melbourne tap water showed that it had the same degree of absorption as sea water. This has important implications in that some of the chemicals which have absorption in the wavelengths under study are actively carcinogenic

Radiation Standards: Radiometer Calibration and Observatory

Standards

The new pyrheliometry laboratory has been completed and now provides excellent facilities for the intercomparison of a number of radiometers simultaneously. A direct link with the Division's computer enables results to be evaluated immediately.

In March 1975 a joint comparison was made between standard pyrheliometers belonging to the New Zealand National Meteorological Service and the (Australian) Bureau of Meteorology on the one hand, and the Division's regional standard on the other.

The instruments comprising the Regional Radiation Standard (W.M.O. Region V) have been augmented by the acquisition of an Active Cavity Radiometer of the type developed by Willson at the Jet Propulsion Laboratory, California, U.S.A. It is anticipated that this type of pyrheliometer which is self calibrating will eventually supersede the Ånström as our primary radiation standard.

Calibration

The interchange of calibrated net pyrradiometers with the Atmospheric Environment Service of Canada has been maintained: this provides a useful cross check on the respective accuracies of the two calibration systems.

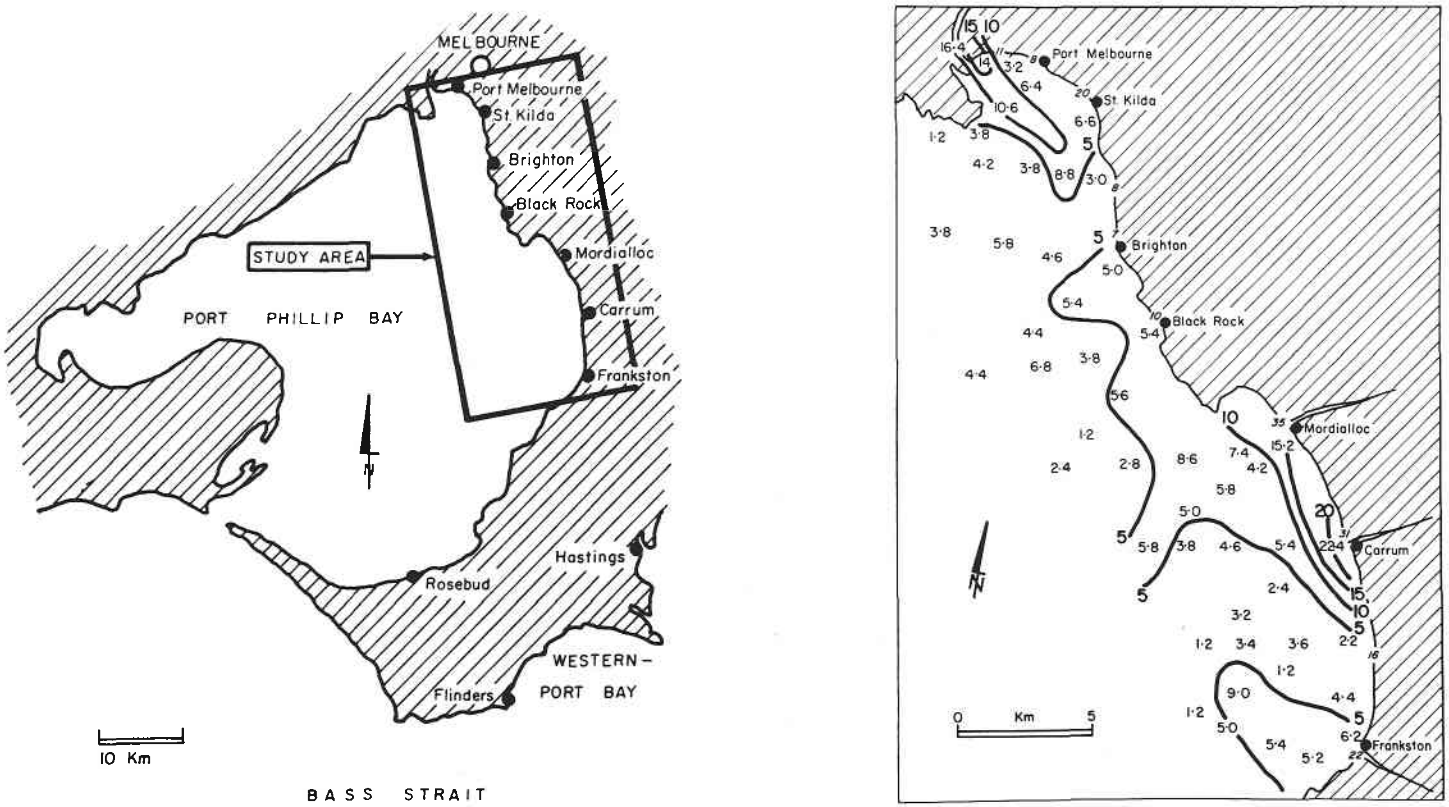


Figure 10: An example of pollution as indicated by U.V. absorption of sea water. Units are arbitrary.

Observatory

This spectral pyranometer previously operating in the visible wavelengths ($\sim$ 400-700 nm) is currently being rebuilt to operate in the U.V. range (290-440 nm).

Analysis of radiation data measured on clear days at Aspendale has yielded simple analytical expressions for the three basic components of solar radiation (global, diffuse and direct radiation) as functions of solar elevation. Such expressions, which could be expected to be of universal application in regions of comparable turbidity, are frequently required for solar engineering and meteorology.

Various types of radiometer have been made available on short-term loan to numerous outside bodies, including the Army Design Establishment, the Horticultural Research Station, Tatura, the Ballarat School of Mines, and Melbourne, Latrobe and Monash Universities.

VIII. OVERSEAS VISITS AND COOPERATIVE VENTURES

Overseas Visits

In July 1974 Dr. G.B. Tucker attended a Study Group Meeting of the Joint Organization Committee (J.O.C.) of G.A.R.P. at Wijk near Stockholm. The subject was "The Physical Basis of Climate and Climate Modelling". He returned to Australia via Senegal, Dakar, where he was able to see at first hand scientific aspects of progress in the G.A.R.P. Atlantic Tropical Experiment. En route he also visited the South African Weather Bureau.

Later, in November 1974, Dr. Tucker took part in the J.O.C/G.A.R.P. meeting in Budapest, Hungary, following this by a visit to the USSR as a member of the Australian Earth Sciences Delegation. During the course of the meeting the delegation was able to inspect the Institute for the Physics of the Atmosphere, Moscow, and the Computing Centre at Novosibirsk in Siberia, one of the main research centres for atmospheric numerical modelling in the USSR.

Towards the end of 1974 Dr. G.I. Pearman undertook an intercomparison of CO_2 calibration gases and to this end spent two months visiting principal CO_2 Monitoring Stations comprising the global network. The objective was to establish the magnitude of the carrier gas error and its importance in the comparability of CO_2 data from the global baseline network. Six compressed gas tanks, containing mixtures of CO_2 in air or CO_2 in nitrogen, were taken to each station where the CO_2 concentration in each tank was measured. The intercomparison confirmed the precision of the system of calibration gases, but showed that at present our understanding of the carrier gas problem is such that atmospheric concentration differences between stations of up to about 2 ppmv can not be established as being either real or erroneous. It is appropriate that we record our appreciation of all those who made this work possible. Included are members of the GMCC section, Air Resources Laboratory, NOAA at Barrow, Alaska, Boulder, Colorado, and Mauna Loa, Hawaii; Dr. C.D. Keeling's group at the Scripps Institution of Oceanography, La Jolla, California; Dr. C.S. Wong's group at the Ocean Chemistry Section, Environment Canada, Victoria, British Columbia; Mr. D.C. Lowe, Nuclear Sciences Institute, DSIR, New Zealand, and Mr. W. Bischof, Institute of Meteorology, University of Stockholm.

Dr. Pearman also:- participated in the Preparatory Workshop stage 2 of the SCOPE medium term programme Project 6 on Environmental Monitoring held in London; attended a meeting of the WMO CIMO working group on air pollution; attended the WMO workshop on the measurement of NO_x held at Chamrousse; and visited several establishments concerned with measurements of atmospheric composition and climatic change; and in March 1975 took part in the WMO meeting of experts on CO_2 held at the Scripps Institution of Oceanography, La Jolla, California.

Dr. Platt visited Europe and the U.S.A. in October 1973 to select a Lidar from among four tenders received by the Division.

In 1974 Dr. Paltridge attended the GARP Study Group Conference on the Physical Basis of Climate and Climate Modelling at Wijk, Sweden. En route he visited meteorological establishments in Europe and the U.S.A. In 1975 he visited Germany to attend the first meeting of the GARP Working Group on Extended Cloudiness and the Radiation Budget, held in Hamburg.

Mr. W. Shepherd spent three months in Europe and U.S.A. in 1974. He attended international conferences at Tel Aviv, Moscow and Paris concerned with evaporation and with the environment and visited several institutions studying movements of natural aerosols in the atmosphere.

As a result of receiving the Carl Gustav Rossby Memorial Fellowship for 1975, Dr. A.D. McEwan is spending six months at the Woods Hole Oceanographic Institution, Massachussetts. His field is the laboratory simulation of various dynamical phenomena in the oceans and atmosphere.

Mr. I.E. Galbally spent nine months in 1973 at the National Centre for Atmospheric Research, Boulder, Colorado, working on Atmospheric Aerosol problems. He visited various other institutions in the U.S.A., Canada, U.K., Sweden and Germany and attended the second IUTAM-IUGG symposium on Turbulent Diffusion in Environmental Pollution at Charlottesville, Virginia in April 1973.

In February 1974 and again in 1975, Dr. J.R. Garratt, Dr. R.J. Francey, Mr. P. Hyson and Mr. G. Grauze, made expeditions to the Ryuku Islands in the East China Sea. They took part in the GARP Atmospheric Transfer Experiment (AMTEX) and using the eddy correlation technique measured the fluxes of heat, water vapour and momentum over the ocean.

At the invitation of the Government of Mauritius Mr. P.D. Berwick recently spent two months in that country as a W.M.O. consultant. The purpose of the visit was to plan the establishment of a micrometeorological unit within the Department of Meteorology.

As part of our Stratospheric Water Vapour Programme Mr. P. Hyson visited the University of Wyoming, U.S.A. in July 1974. The objective was a comparison between the Division's infrared hygrometer and an aluminium oxide sensor employing balloons as carriers. The results have been published in an internal report of the University (see Section IX 'Publications').

Cooperative Ventures

Studies of the composition of air trapped in ice cores from Antarctica and of the stable isotope ratios in tree rings are being undertaken with Dr. W.F. Budd and Mr. V. Morgan of the Glaciology Section of ANARE.

Shortly the Division expects to start measurements on freon II and carbon tetrachloride in the free atmosphere. A suitable gas chromatograph and detector is being acquired on loan through the good offices of Dr. J.E. Lovelock, Department of Applied Physical Sciences, University of Reading.

Through the cooperation of Mr. B.N. Nollar, Chemistry Department, University of Tasmania, some preliminary measurements of the concentrations of several heavy metals (including lead and cadmium) in atmospheric particulates collected at Hobart have been made. The acquisition of an atomic absorption spectrophotometer will enable us to expand this programme in the near future to measure heavy metals in samples from all stations in the surface air sampling network.

Australian Baseline Station

In the introduction of the Division's last report, it was stated that "we look forward to the establishment in Australia of a 'base-line' station, along the lines of the World Meteorological Organization's recommendation, capable of sustaining a long-term series of high quality observations". Members of this Division have continued to work together with the Division of Cloud Physics and the Australian Departments of Environment and Science and Consumer Affairs in an effort to establish guide lines for the development of such a station. This has involved participation on an inter-departmental committee which has considered the organizational alternatives available. In addition a network of climatological stations has been established in southern Tasmania to enable the determination of patterns of local wind direction, wind speed and solar radiation in the area nominated to be most suitable for the baseline station.

Flight Activity of Locusts

In September 1973, moth migration to Tasmania from the mainland was observed by radar during the course of a joint experiment with the Division of Entomology. These moths may play a significant part in army-worm infestations of grassland. In February and March 1974 radar observations of the flight activity of high concentrations of locusts were made at Benalla and Narrabri. These studies confirmed earlier radar observations that massive insect migration can take place in the early hours of the night, stressing the need for spatial description of winds in the lowest kilometre or so.

Other

In 1973 Dr. P.G. Baines gave a course of lectures on atmospheric and oceanic dynamics in the Department of Mathematics, Monash University.

Mr. Galbally is giving a series of lectures on the composition and chemistry of the atmosphere to honours students at the Department of Meteorology, University of Melbourne.

Sponsored by W.M.O., Mr. Rodjali of Indonesia and Mr. N.S. Boulahya of Algeria both spent a year with the Division as visiting Fellows. Mr. A.M.A.H. Omara of Egypt, also on W.M.O. Fellowship, worked in the Division for some 4 months. In all three cases, the Fellows were studying the application of agro-meteorological techniques.

Mr. H.J. Son of the Korean Meteorological Services spent 18 months in the Division as a Fellow under the Colombo Plan: he studied the occurrence of severe local storms in Australia.

IX. PERSONNEL – MOVEMENTS AND AFFILIATIONS

It is with great regret that we report the death of Dr. W.W. Mansfield in December 1974, six months after he joined the Division.

In December 1974 Mr. R.H. Clarke, Leader of our Dynamic and Synoptic Group, resigned to take up a new appointment as Officer-in-Charge, Australian Numerical Meteorology Research Centre, Melbourne.

New Appointments

In September 1973 Dr. P.G. Baines, who for the preceding two years had been the holder of a Queen's Fellowship in Marine Science, joined the Division to work on theoretical fluid dynamics.

Towards the end of 1973 Dr. R.J. Francey from the Simon Fraser University, Canada, joined the Division. He will be concerned with air/sea interaction problems.

A former Post-doctoral Fellow in the Research School of Chemistry, Australian National University, Dr. B.L. Sawford was appointed to the Division in October 1974 to work on theoretical studies of mesoscale phenomena.

Dr. J.S. Frederiksen, a Post-doctoral Fellow at the Institute of Theoretical Physics, University of Groningen (Netherlands) joined the Division in December 1974 to develop numerical models in the context of climate.

In mid 1974 Dr. P.J. Fraser from the Australian National University was appointed to work in the field of atmospheric chemistry.

Affiliations

Dr. G.B. Tucker is a member of the Joint Organizing Committee, GARP; Australian Academy of Science National GARP Committee; Australian National Committee on Geodesy and Geophysics, Sub-Committee for Meteorology and Atmospheric Physics; Australian National Committee for Antarctic Research – Sub-Committee on Meteorology; Australian National Advisory Committee for UNESCO, Man and the Biosphere Programme; Australian Institute for Defence Science; Pacific Science Committee; CSIRO Advisory Committee on Computing; and the Australian Academy of Science Ad Hoc Committee on Climate Change.

Dr. A.J. Dyer is a member of the Australian Academy of Science Ad Hoc Committee on Climate Change; Australian Academy of Science National Scientific Committee on Problems of the Environment; National Committee for Geodesy and Geophysics (including the Sub-Committee for Meteorology and Atmospheric Physics); Australian Academy of Science, National Committee for Space Research; IAMAP Committee on Atmospheric Chemistry and Global Pollution; AMTEX Steering Committee; and the ICSU

Committee on Space Research. He is also, Vice-President for Australia, Royal Meteorological Society and Chairman, Australian Branch, Royal Meteorological Society.

Dr. R.N. Kulkarni accepted an invitation to become the Chairman of the Working Group on Atmospheric Ozone for Region V of the W.M.O. He is a member of the International Ozone Commission of the I.A.M.A.P.

Mr. R.J. Taylor has been appointed Chairman of the W.M.O. Commission of Atmospheric Science Working Group on Atmospheric Boundary-Layer Problems for the 4-year period 1974-1977.

Dr. G.W. Paltridge is a member of the International Commission on Atmospheric Electricity, Working Group No. 3, and the Ad Hoc Working Group for JOC for GARP – Extended Cloudiness and Radiation.

Dr. G.I. Pearman is a member of the W.M.O. Working Group on Air Pollution Measurement.

Dr. A.B. Pittock is Technical Secretary to the Climate Change Committee of the Australian Academy of Science.

X. MISCELLANEOUS

The year saw the practical completion of a new wing to the Division. Besides the addition of offices and laboratories, the Machine Shop was enlarged and an up-to-date lecture theatre established.

Standards

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 solar and thermal 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.

Increased attention has been given to communication with the general public and to this end talks have been given over the radio and to community groups such as Rotary. Scientific reports have been supplemented by others of a more general nature directed to the intelligent layman.

XI. PUBLICATIONS

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XII. STAFF

CHIEF

G.B. Tucker, B.Sc., Ph.D., D.I.C.

ASSISTANT CHIEF

A.J. Dyer, Ph.D., D.Sc.

MANAGEMENT

P.D. Berwick, B.Sc. (Technical and Scientific)

F.K. Tighe, B.A., M.I.A.A. (Administration)

SCIENTIFIC AND PROFESSIONAL

N.E. Bacon, B.Sc.
P.G. Baines, B.Sc., B.A. Ph.D.
I.J. Barton, B.Sc., Ph.D.
D.J. Beardsmore, A.R.M.I.T.
R.C. Bell, B.Sc.
B.G. Collins B.Sc.
A.C. Dilley, B.Sc.
R.J. Francey, B.Sc., Ph.D.
P.J.B. Fraser, B.Sc., Ph.D.
J.S. Frederiksen, B.Sc., Ph.D.
I.E. Galbally, B.Sc., M.Sc.
J.R. Garratt, B.Sc., Ph.D.
R.H. Hill, Dip.E.E., B.E.
P. Hyson, B.Sc., M.Ph.
R.N. Kulkarni, M.Sc., Ph.D.
F.J. Maher, A.R.M.T.C.
P.C. Manins, B.Sc., B.E.(Mech), Ph.D.
A.D. McEwan, B.E. M.Sc., Ph.D.
R.R. McGregor, Dip.Appl. Sci.
I.C. McIlroy, B.Sc.
G.W. Paltridge, B.Sc., M.Sc., Ph.D.
G.I. Pearman, B.Sc., Ph.D.
A.B. Pittock, B.Sc., M.Sc., Ph.D.
C.M.R. Platt, B.Sc., M.Sc., Ph.D.
H.A.H. Rabich, Dipl. Phys.
B.L. Sawford, B.Sc., Ph.D., D.I.C.
W. Shepherd, M.Sc., M.Agr.Sc.
K.T. Spillane, B.Sc., Ph.D.
R.J. Taylor, M.Sc.
A.J. Troup, B.Sc.
E.K. Webb, B.A. B.Sc.

TECHNICAL SUPPORT

Mrs. J.M. Bathols
J.W. Bennett
Mrs. A.J. Campbell
F.R.E. de Silva
D.G. Dowe
C.C. Elsum
C.M. Elsworth
G.L. Garnham
Mrs. H.S. Goodman
G. Grauze
R. Hall
I.D. Helmond
S.M. Kepert
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G. Liubicich
R.E. Meyer
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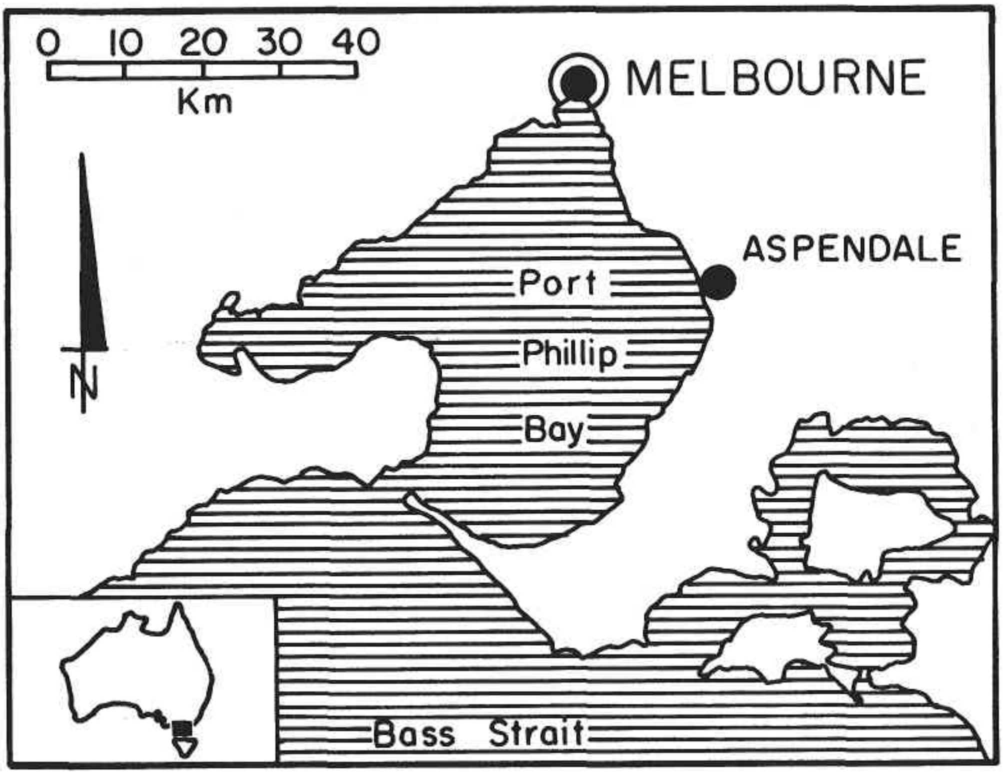
P.J.B. Nelson
J.G. O'Toole
D.J. Pack
G.R. Patterson, A.R.M.I.T.
D.G. Reid
N.G. Richards
G.F. Rutter
G.O. Scott
J. Stevenson
L.G. Tout
J. Wren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Km
MELBOURNE
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