CSIRO Division of Atmospheric Research

Research Report 83-85

Cover:
The "Melbourne Eddy" (also known as the "Spillane Eddy") was first identified on the basis of local windfield observations. It is responsible for keeping polluted air over the Melbourne area during summertime air pollution episodes. The eddy develops in the lee of the Great Dividing Range on days of weak easterlies, with a low level temperature inversion trapping motor vehicle emissions.

Geophysical fluid dynamics experiments first carried out in the 1970's by Dr Kevin Spillane, a former member of the Division, allow this phenomenon to be studied under controlled conditions. A model of Victoria is towed through a tank filled with water, simulating the easterly wind. The water consists of layers of decreasing salt content, simulating the stably stratified air. Dye released in selected locations traces out the local flowfield.

On 22 February 1984, a unique satellite image was captured by the Division's CSIDA facility. The image shows early morning fog over Melbourne on a day of weak easterlies and high air pollution potential. The similarity between the eddy as marked out by the fog and the fluid motion marked by the dye in the GFD experiment is striking.

Contents

Foreword

This report is a description of the first two years of activity of the new Division of Atmospheric Research.

The Division works primarily in an area where public funding is mandatory since there is no incentive for private funding of the basic and wide-ranging research being done. Such research nevertheless provides the framework of understanding essential to the development of sound applications.

The Division's rationale for the main research program structure is based on a four-fold approach to atmospheric research, involving:

. . . The material structure of the atmospheric system (atmospheric constituents).

. . . The primary forcing mechanism (solar and terrestrial radiation, together with clouds which are a principal interactive control on the radiation budget).

. . . The dynamical response of the system on a regional scale (small-scale dynamics).

. . . The dynamical response of the system on a planetary scale (large-scale dynamics).

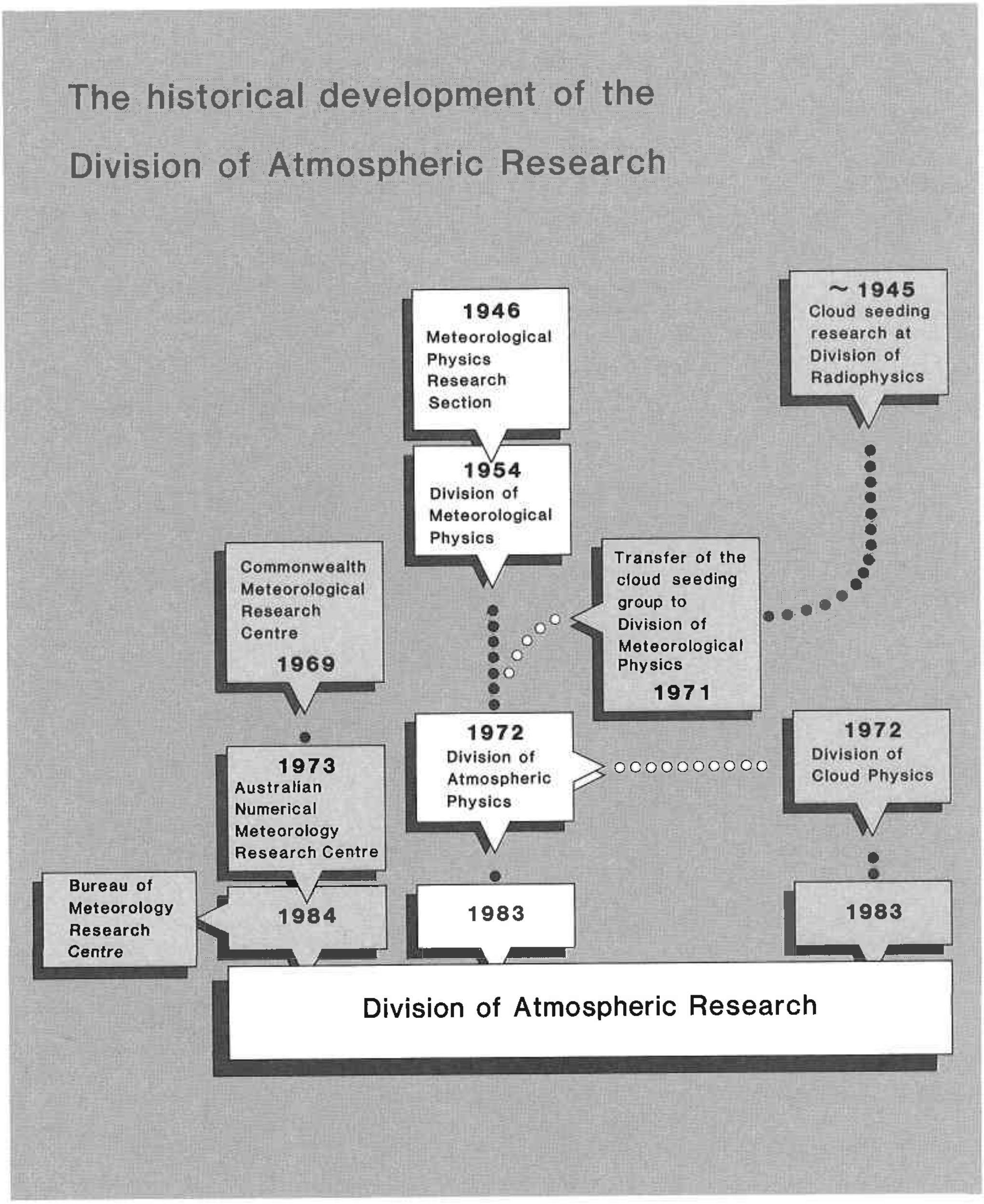
From the beginning the Division had three broad motivations: to perform high-quality science, to achieve a balanced program in the strategic-tactical spectrum, and to apply research results for the benefit of Australia. The following pages show the extent to which these motivations have been effective. An attempt has been made to strike a balance between core research and projects of a more direct relevance, while at the same time responding positively to Government exhortations to scientists to provide support for Australian industry.

I am particularly grateful to Dr Willem Bouma who was solely responsible for preparing this report.

G. B. Tucker,
Chief of Division.

A new Division

In 1983, acting on the recommendations of a committee which had the task of reviewing atmospheric science in CSIRO, the CSIRO Executive decided that a more integrated effort was needed in atmospheric research. This was put into effect by the amalgamation of the Divisions of Atmospheric Physics and Cloud Physics and the CSIRO component of the Australian Numerical Meteorology Research Centre (ANMRC). The new Division was to be called the **Division of Atmospheric Research** and all staff were to be located at the Aspendale site.



The Executive, in its decision to create the new Division, listed its objectives as:

> *. . . to conduct research into physical and chemical aspects of atmospheric processes and phenomena, including both basic studies and investigations directed towards the solution of environmental, industrial and community problems.*

Upon the formation of the new Division, **Dr Brian Tucker**, former Chief of the Division of Atmospheric Physics, was appointed as Chief. Staff of the Division of Cloud Physics, based in Sydney, had to transfer to Melbourne, or find employment elsewhere and the closure of ANMRC was to be finalised with the Bureau of Meteorology. Consequently, it was only on the first of September 1985 that the Cloud Physics Laboratory in Sydney ceased to exist. Until that time the Laboratory had operated in Sydney as part of DAR, with **Dr Chris Coulman** as Officer-in-Charge. The ANMRC closed on the first of January, 1985; 4 staff members joined DAR, the remainder were transferred to the Bureau of Meteorology. (A further 6 were to be relocated from the Bureau to the Division over the next 3 years).

Research programs

Under Dr Tucker's direction the research programs for the new Division were charted, and promulgated in a publication ("Research Programs in the CSIRO Division of Atmospheric Research", February 1984). It was decided to pursue the Division's objectives via four research programs. These programs and sub-programs, as of the close of the period described in this report, are listed below.

Current research programs in the Division of Atmospheric Research

Research programs	Subprograms
Atmospheric constituents	Reactive gases and aerosols Distribution and transport Baseline Air Pollution Station*
Clouds and radiation**	Satellite remote sensing Lidar Industry collaboration
Small-scale dynamics	Mesoscale processes Environmental dynamics Bushfire research*
Large-scale dynamics	Atmospheric dynamics Climate modelling Diagnostics

30/6/85

*Funded in part from outside the Division

**Will from July 1986 be known as "Remote sensing".

A Divisional Advisory Committee

In a move to ensure the Division's accountability and to strengthen the Division's support from outside CSIRO, Dr Tucker decided in 1983 to invite a number of prominent figures to serve on a **Divisional Advisory Committee**. The Committee's terms of reference are:

i To advise the Chief on policy matters. This involves interpretation of the objectives of the Division and the priorities to be followed bearing in mind other relevant scientific activities both inside and outside CSIRO.

ii To keep itself informed of the broad direction of current and planned work in the Division and to advise the Chief on the best way to make this work known to interested persons and organizations in Australia.

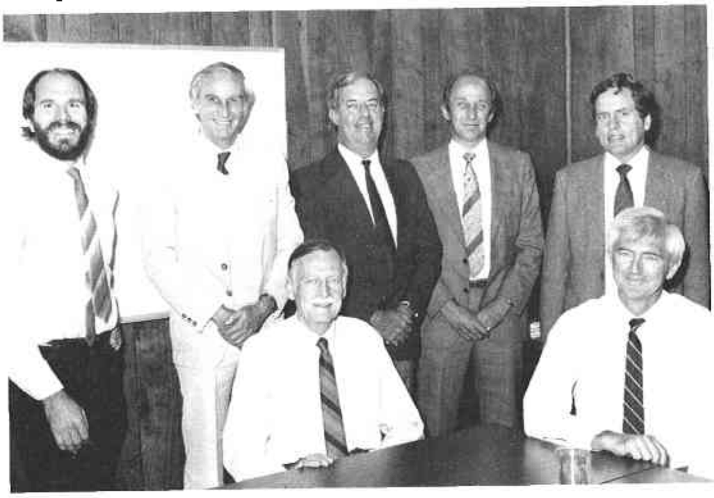
iii To identify the interests of the Australian community that may be furthered by the Division.

iv To advise on any other matter that may be referred to it by the Chief.

Meetings of the Divisional Advisory Committee are held twice a year, and the first meeting was in February 1984. The membership of the first Committee (1984–1985) was:

Mr Hal Holmes, Chairman of Monsanto Australia Ltd.
Mr Bob Chynoweth, MHR, Federal Member for Flinders (now Dunkley)
Dr John de Laeter, Dean of Science, WAIT
Mr Richard Llewelyn, Manager, Research & Development, SECV
Capt. Geoff Molloy, Qantas Airways Ltd.

During the first two years of its existence the Committee has been very successful, and it is envisaged that such a committee will from now on be a permanent part of the Division's makeup. Indeed, DAR's Advisory Committee has been held up by CSIRO as an example for other CSIRO Divisions to follow.



The first Divisional Advisory Committee. From left to right: Seated — Hal Holmes (Chairman) and Brian Tucker (Chief of Division); Standing — Willem Bouma (Secretary), John de Laeter, Geoff Molloy, Richard Llewelyn and Bob Chynoweth.

Collaboration and cooperation

As in previous years, DAR scientists are collaborating with colleagues in Australia and overseas. In Australia this involves scientists in the Australian Bureau of Meteorology, the Universities, and other research organizations such as the Australian Government Analytical Laboratories and the Australian Atomic Energy Commission. (See also the discussion of CSIRO/University research grants below).

Overseas collaboration is occurring via a large number of Universities and Institutions, the most prominent being the National Center for Atmospheric Research (NCAR) in Boulder, Colorado, the National Oceanic and Atmospheric Administration (NOAA), the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, and the Colorado State University. More information on DAR's interaction with other Institutions is contained in the reports on visitors to DAR and in the Personnel section.

In the Melbourne area, a formal mechanism for keeping in touch is via the joint seminars organized between DAR, the Bureau of Meteorology and Monash University, while DAR staff are active also in the Australian Branch of the Royal Meteorological Society. Finally, a number of DAR staff have been formally associated with the Universities, as listed below.

Lecture courses and affiliations with Australian Universities

University		Lecturer and course details
Monash	1983 & 1985	J.R. Garratt Lecture course on "Atmospheric Boundary-Layer" for Honours and MSc students.
Monash	1985	R.A. Plumb Lecture course on "The Middle Atmosphere" for Honours and MSc. students.
Melbourne	1983 & 1984	I.E. Galbally and G.P. Ayers Lecture course on Composition and Chemistry of the Atmosphere for Graduate Students in the Department of Meteorology (includes students from the Bureau of Meteorology Training School for Meteorologists).
Melbourne	1983 & 1984	A.B. Pittock Lecture course on "Planetary Climatology: Climate Change and Variability" for Second Year Meteorology students.
Melbourne	1983	G.L. Stephens Lecture course on "Atmospheric Radiation" for Meteorology students.
Melbourne (RAAF, Pt Cook)	1984 & 1985	G.W. Paltridge Lecture course on "Thermodynamics" to Second Year students.
Latrobe	1984 & 1985	B.G. Hunt Honorary Research Fellow, Department of Physics. Occasional seminars and interaction with students and staff.
Wollongong	1984	P.J. Fraser Lecture course on "Atmospheric Chemistry" to Honours and MSc. students in the Chemistry Department.

Staff and finance

The new Division of Atmospheric Research has some 130 staff, of which about half are professional (research and experimental scientists). Appropriation Funding for 1983/84 and 1984/85 was $5.42m and $5.56m respectively. Contributory funding for 1983/84 totalled $.187m and for 1984/85 $.188m. The majority being for CGBAPS (Cape Grim Baseline Air Pollution Studies) actitivies and NERDDC (National Energy Research, Development and Demonstration Council) projects. In addition a number of applications for CSIRO/University Grants were successful with the grant money being made available direct to each collaborating university.

Contributory funding : CGBAPS, NERDDC and CSIRO/University grants

Project	Lead scientists
CGBAPS 83/84 & 84/85 "Baseline Air Pollution Studies"	G.P. Ayers, E.K. Bigg, R.J.Francey, P.J. Fraser, I.E.Galbally, J.L. Gras, G.I.Pearman and C.M.R. Platt
NERDDC 83/84 & 84/85 "Meridional carbon dioxide and $^{13}C/J^{12}C$ gradients"	R.J. Francey
DAR/Monash University 83/84 & 84/85 "Analysis of the Southern Hemisphere stratospheric circulation, using satellite data".	R.A. Plumb and D.J. Karoly
DAR/University of Melbourne 84/85 "Determination of the factors responsible for the inefficiency of fertilizer nitrogen applied to irrigated summer crops"	I.E. Galbally, J.R. Freney and P.M. Clarke
DAR/University of Melbourne 84/85 "Cold Fronts Field Experiment"	B.F. Ryan, J.R. Garratt and T.Gibson
DAR/Monash University 84/85 "Cold Fronts Field Experiment"	B.F. Ryan, J.R. Garratt and R.K. Smith

Highlights 1983–1985

In the detailed reports which are presented in the following pages, summaries are provided for the research carried out at DAR in the period covered. However, some events and achievements are worth a special mention.

The Atmospheric Constituents program has arrived at a period where international recognition and appreciation of the trace constituent research based on our work involving the Cape Grim Baseline Station has become clearly evident. The value of the research on global increases in trace gases such as carbon dioxide, methane and halocarbons lies especially in the improved understanding of the underlying mechanisms responsible for the production, transport and distribution of these gases. A recent initiative which shows a lot of promise is an attempt to measure trace gases from air bubbles trapped in Antarctic ice cores, enabling scientists to obtain values of atmospheric trace gas concentrations from before the industrial revolution.

An important event in the Clouds and Radiation group was the completion of the development stage of the **CSIDA** (CSIRO System for Interactive Data Analysis) facility at DAR. This satellite data acquisition and image processing facility includes a tracking antenna for receiving information from polar-orbiting satellites, as well as hardware and software for rapid analysis of the data received. The system is now being produced commercially by two Melbourne companies: **PCM Electronics Pty Ltd**, and the **Dindima Group Pty Ltd**. The systems manufactured by the two companies are fully compatible, and are expected to find a market in Australia and the Australian Pacific region. Other developments in the Clouds and Radiation group are further moves to become involved in the development of space-based instruments for environmental monitoring satellites. These developments are supported by CSIRO's nomination of space research as a priority research area.

In the Small-scale Dynamics Group research in support of the **Latrobe Valley Airshed Study** (LVASS) continued, while the significance of DAR's contribution was highlighted by the fact that Dr Peter Manins was seconded from DAR to become the Project Director for the LVASS for three years. The third and final observational phase of the **Cold Fronts Research Program** (CFRP) took place in November 1984. The CFRP was a collaborative effort between DAR and the Bureau of Meteorology, with support of the Universities and many other Institutions. Detailed analysis of the results of the first two field studies has led to a conceptual model of the summertime cool change, and formed the basis for the planning of this third and final observational phase. Analysis of the new data will continue for some time. The latest development in the Small-scale Dynamics Program is a collaborative effort with the newly established National Bushfire Research Unit in Canberra, where DAR's expertise will be applied to studies of bushfire meteorology.

With the formation of the new Division and the subsequent reorganization, the Large-scale Dynamics Group became the fourth research program in the Division. In the last two years the Group has gained additional resources, and seen the transfer of Mr Barrie Hunt from ANMRC to join DAR. In 1984 Dr Jorgen Frederiksen was awarded the David Rivett medal by the CSIRO Officers Association, in recognition of his work in atmospheric physics. Research in the Large-scale Dynamics Program was recently bolstered by the recognition of the Institute of Physical Sciences of 'Drought Research' as an Institute priority research area. At the end of the period reported here, two new appointments to strengthen this research were imminent. Finally, DAR's expertise in large-scale dynamics will be used in a limited study of the environmental consequences of a Northern Hemisphere nuclear war. The study will concentrate on the interhemispheric transport of soot and smoke, and is funded by an International Year of Peace grant. Scientists in the Atmospheric Constituents Program will contribute with studies of the fireball chemistry and dynamics of nuclear explosions on stored and/or naturally occurring fossil fuels.

The public profile of DAR has been raised substantially in recent years. This has been brought about by a greater contact with the media: more newspaper stories on DAR's research, excellent coverage of DAR's activities by CSIRO's magazine on science and the environment, ECOS, and a number of interviews on local and national radio. The most significant of these was no doubt the series of Friday morning talks given by Dr Tucker on ABC-radio.

Such activities, though necessary to ensure public awareness of our research and its value to the community, only serve to support the real purpose of the Division: to carry out research into problems of weather, climate and air pollution. These activities are described in the following research reports.

Atmospheric constituents

Introduction

The atmospheric constituents program is concerned with the composition and chemistry of the atmosphere on a global, regional and local scale. Airborne material, whether gaseous or particulate, plays an important part in regulating the Earth's climate as well as exerting a direct influence on life processes. It can pollute the atmosphere and cause health problems or damage the environment; it can upset the chemical composition of the atmosphere, and, for example, through increasing carbon dioxide levels modifying the radiation balance and hence climate, it can affect the Australian economy and society.

Many of the substances found in the air occur naturally, but the products of industrialization processes or man's land-use practices may increase their concentration or introduce foreign material. The research program makes use of and supports the facilities of the **Baseline Air Pollution Station at Cape Grim**, Tasmania. The CGBAPS facility provides the all-important measurements of the background levels of the atmospheric trace gases. The research effort is conveniently divided into research dealing with studies of distribution and transport processes of atmospheric trace gases, and studies of chemically reactive gases and aerosols. The latter subprogram includes studies of rainwater chemistry, a topic which has gained prominence in recent times due to the rainfall acidity problems experienced in western Europe and parts of northern America.

Finally, some research into aspects of the environmental effects of nuclear war has been carried out. The work has concentrated on the properties of smoke and soot which is postulated to have such a dramatic effect on the incoming solar radiation (see description in the Large-scale Dynamics report). This research will continue in 1985/86 when it will be funded by an International Year of Peace grant.

Distribution and transport

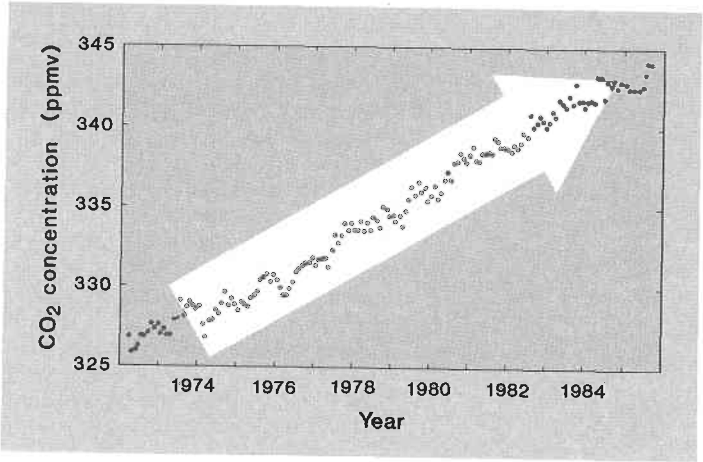
The global distribution of current levels of atmospheric trace gases reflects the surface sources and sinks, and chemical transformation which may take place in the atmosphere, and the effectiveness of atmospheric transport. Thus, particularly for species where chemical transformation is well understood or very slow, global distributions can be interpreted in terms of surface exchanges given an adequate description of the transport. A major objective of the research program has been to infer the temporal and spatial magnitude of surface exchanges of several species utilizing the global observations from various Baseline Stations (see below) in the context of a global atmospheric transport model.

The ultimate aim of the research is to use this detailed understanding of the distribution of the trace gases and transport processes which affect them to allow estimates of factors influencing surface exchanges and the capability of predicting future levels of these trace gases. Critical both to our knowledge of sources and sinks and to prognoses of the future is the way in which the biosphere interacts with and is affected by the various atmospheric constituents.

Carbon dioxide

Analysis of CO_2 data collected at Cape Grim is continuing, while analysis of data collected by aircraft from over the Australian region has been completed. The aircraft data, collected from 1972 to 1981, provided detailed insight into the natural variability of CO_2 concentration at all levels of the troposphere and lower stratosphere.

The magnitude and phase of annual and interannual variations observed over Australia and Antarctica in this program, combined with other global data, provide a quantitative description of the transport and spatial distribution of surface fluxes of this gas.



These CO_2 measurements are from aircraft sampling of air in the middle troposphere over southeastern Australia. They show a steady increase in CO_2 of about 0.4%/year.

Global transport of carbon dioxide

Using a two-dimensional transport model the estimated air-to-surface exchanges of carbon dioxide have been related to spatial and temporal variations of atmospheric CO_2 concentrations and isotopic composition. The atmospheric model, coupled with models of the biosphere and mixed layer of the ocean, describes the gross features of the global carbon cycle.

From a comparison between model generated CO_2 concentration variations and the variations observed on secular, interannual and seasonal time scales, together with the relationship between isotopic and concentration variations, conclusions may be drawn regarding the contributions from various sources to the carbon cycle. The results show how the global distribution is, on average, determined primarily by fossil fuel release and that there is no clear evidence for large, net releases from the biosphere; the isotope data support these results. Indeed, it should be possible to use the isotope data to ascribe a magnitude to the oceanic and biospheric components that make up the seasonal variation of CO_2 in the Southern Hemisphere.

Global carbon cycle modelling

The main recent development in the global carbon cycle modelling program has been a refinement of the mathematical techniques involved. This has involved the use of simple analytic models as a guide to the most appropriate numerical modelling calculations. There has also been extensive development of new calibration techniques based on approaches common in other geophysical disciplines such as seismology.

The implementation of a range of models has made it possible to select the most appropriate level of modelling for any particular problem so that attention can be focused on the essential aspects of the problems. Simple response function models have been used in the deconvolution of indirect data such as the carbon-13 record from tree-rings and the CO_2 record from ice cores.

The more detailed global carbon cycle developed within the Division has been recalibrated using techniques of constrained inversion that have proved robust and stable. The calibration procedure has allowed a systematic investigation of the relative importance of the various types of observations of the carbon cycle for the purpose of reducing existing uncertainties concerning the current state of the carbon cycle. The main uncertainties at present concern the extent to which the terrestrial biomass has changed over the last 100 years. The results of carbon cycle modelling appear to be consistent with preliminary measurements of CO_2 in ice cores but remain inconsistent with direct estimates of biospheric changes based on ecosystem modelling.

Atmospheric transport modelling

The further development of atmospheric transport models has been in three areas: mathematical analysis of ways of using the models, improvements in the numerical procedures and the use of transport coefficients derived from a general circulation model (See the Large-scale Dynamics report). Preliminary studies with a new model incorporating these changes have been a re-examination of the distribution of radiocarbon from nuclear testing. The results indicate an anomaly in the stratosphere- troposphere transport and this is under further investigation. The seasonal variation of CO_2 has been investigated using new computational procedures for deducing surface source strengths. One ongoing study is analysing these calculations to determine the extent to which the space-time variation of surface sources can be resolved, given the resolution of the existing global CO_2 monitoring network.

Isotope measurements

Throughout the period measurements of $\delta^{13}C$ in Cape Grim Air continued. Analysis of the 1982–84 data identified CO_2 exchange with the biosphere as the cause of the seasonal CO_2 concentration variation at mid-southern latitudes, and demonstrated a dimunition and phase lag of the South Pole signal consistent with the influence of ocean exchange. The long term isotopic change due to fossil fuel combustion, modified by ocean exchange, was also measured. The program also collects information on the $\delta^{13}C$ in CO_2 and the interpretation of apparent geophysical signals in these data has commenced.

A program to measure the latitudinal and seasonal variations in $\delta^{13}C$, CO_2, CO, CH_4, N_2O and halocarbons, was implemented at the end of 1983. Funding to operate this program for two years was received from NERDDC. Two clean, dry air samples are collected each month from each of Alaska, Hawaii, Samoa, Tasmania and the South Pole.

Measurement of $8^{14}C$ in air by chemical trapping of CO_2 at Cape Grim continues. Plans to markedly improve sampling control, using short term cryogenic trapping and accelerator-mass spectrometer assaying is being implemented. A new program to trace CO_2 exchange using measurements of Oxygen/Nitrogen ratio to part per million accuracy has been commenced at Cape Grim.

A pilot program to look for a sea surface temperature record in the isotopic composition of coral is also underway.

Research on carbon isotopes in tree-rings has been phased out after discovering an interdependence between the record of fossil fuel induced atmospheric variation and the physiological fractionation in trees. In the course of this work several apparent inconsistencies in previous tree ring isotope results were reconciled, and new areas of research were suggested involving the use of isotopes to measure integrated physiological responses of trees to environmental change.

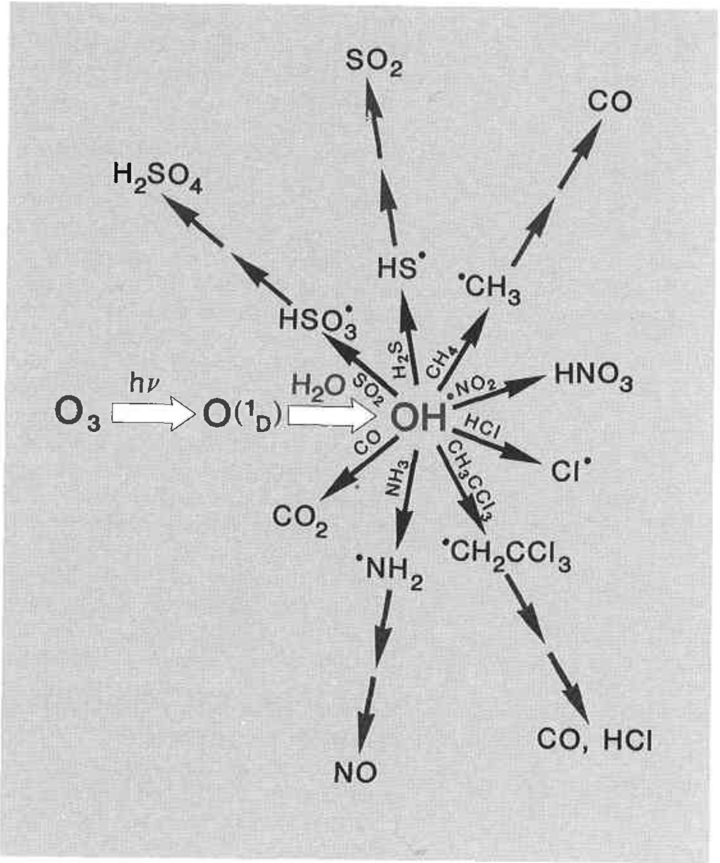
Methane, methyl chloroform and carbon monoxide

The chemical composition of the unperturbed troposphere is dynamically balanced and largely controlled by the global biosphere. Human activities can alter this equilibrium and induce changes in atmospheric composition. As a consequence of energy demands, agricultural and industrial practices, gases such as carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), a number of halocarbons (CCl_3F, CCl_2F_2 CH_3CCl_3, CCl_4, $CHCl_2F$, $CBrCl_2F$, CCl_2FCClF_2) and possibly carbon monoxide (CO) are increasing in concentration on a global scale. A long term accumulation of these gases will directly or indirectly cause an increase in the earth's infrared opacity, possibly inducing changes in climate, the hydrological cycle, tropospheric photochemistry and the biogeochemical cycling of nutrient elements.

Hydroxyl radical (OH), formed in the background troposphere by photochemical reactions involving ozone (O_3), provides an efficient, global scale scavenging mechanism for many man-made and natural trace gases (See illustration below). The essential role of OH in tropospheric chemistry was recognized in the early 1970's, but it remains a difficult species to measure directly and thus little is known of its temporal and spatial variability. Trace species whose sources are known and whose major sink is reaction with OH can provide indirect evidence of such variability. A relevant example is methylchloroform (CH_3CCl_3). If the atmospheric behaviour of OH can be quantified in this way, the source strengths of CH4 and CO can be deduced, since their major sink in the atmosphere is reaction with OH.

Methane

Methane (CH_4) concentrations at Cape Grim in Tasmania, Mawson in Antarctica and throughout the troposphere over southeastern Australia are increasing (1.1–1.2% in 1984) and the rate of increase is constant. Methane also shows a distinct annual cycle at Cape Grim and Mawson, with an overall shape and phase similar to CH_3CCl_3.



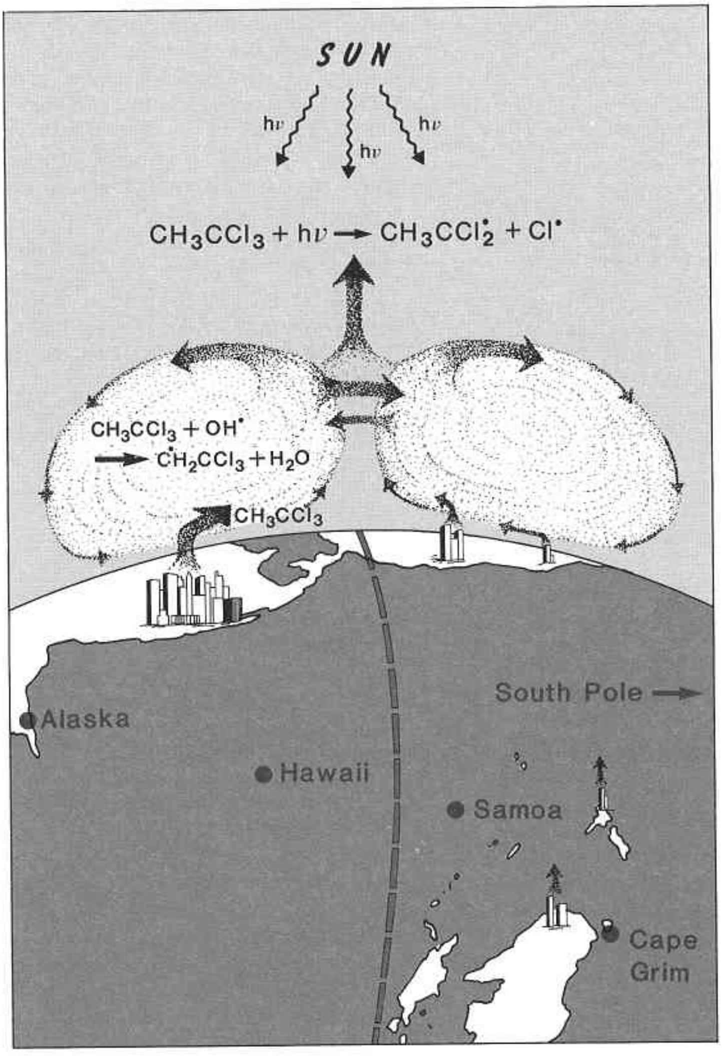
The hydroxyl radical (OH•) plays a central role in the oxidation of trace gases in the lower atmosphere.

The amplitude of the annual cycle is small in the mid-troposphere and virtually disappears in the upper troposphere. There is evidence of an annual average vertical gradient of CH_4 in the troposphere of approximately 1.5 ppbv/km, with lower concentrations at the surface.

Modelling studies suggest that a global CH_4 source of $470'10^{12}$ g/year is consistent with the OH levels deduced from CH_3CCl_3 studies. This results in an atmospheric lifetime of 10 years for CH_4. Almost twice as much CH_4 is released in the northern hemisphere than in the southern hemisphere, reflecting its largely terrestrial origin. The observed annual cycle of CH_4 at Cape Grim is due to seasonal variations of OH with atmospheric transport playing a minor role. The cause of the observed decay with altitude of the amplitude of the annual cycle has not yet been identified, nor has the origin of the observed vertical gradient. Modelling studies are proceeding to tackle these questions.

Methyl chloroform

Concentrations of methyl chloroform (CH_3CCl_3) at Cape Grim are increasing (3% in 1984) but the rate of increase is slowing down due to the relatively constant recent emissions. CH_3CCl_3 exhibits a well defined annual cycle with a broad, spring maximum and a narrow,



The principal source of halocarbons in the atmosphere is the heavily populated and industrialized Northern Hemisphere. The diagram illustrates the global transport and degradation modes for methyl chloroform, and the five Baseline Air Pollution Stations where observations are carried out.

late summer minimum. Modelling studies suggest that the annual cycle is due largely to seasonal variations in the hydroxyl radical (OH), whose average concentration in the troposphere is 7×10^5 Jmolecules/cm^3, resulting in an average lifetime of CHM_3CCl_3 in the atmosphere of approximately 6 years.

Carbon monoxide

Concentrations of carbon monoxide (CO) at Cape Grim and Mawson are identical and show no evidence of increasing with time. Concentrations in the middle and upper troposphere also show no increase but are, on average, 10% higher than those observed in the boundary layer. A distinct annual cycle, similar in phase and amplitude to CH_4 at Cape Grim, is apparent throughout the troposphere, presumably in response to OH variations. Attempts are underway to model the global behaviour of CO.

Ice core studies

Measurements

In collaboration with the Antarctic Division, a project is underway to determine the concentrations of trace gases such as carbon dioxide, methane and nitrous oxide from air bubbles trapped in antarctic ice. The ice cores, which were drilled and collected by scientists from the Antarctic Division, can be dated by the ^{18}O content of the ice (which shows seasonal variations). The aim of the trace gas analysis program is to obtain accurate information on the pre-industrial levels of these gases. Towards the end of the period covered in this research report the program was meeting with success: pre-industrial concentrations of carbon dioxide have been shown to be around 280 ppmv, some 65 ppmv below the current (1985) level of 345 ppmv.

Theoretical studies

In parallel with the program of measuring the composition of air bubbles in ice cores, a number of mathematical studies have been undertaken in order to clarify the interpretation of the concentrations that are measured. The first group of studies has determined the details of the trapping process that need to be known in order to assign an effective age to the gas in a given ice layer. In particular the question of calibrating the trapping process using a tracer with a known history of atmospheric change has been investigated. While this approach has been found to be unsuitable for analysing general variations it is a useful way of assigning an effective age if both the calibration tracer and the gas whose history is sought both show a regular increase.

Other mathematical studies have modelled the statistics of the trapping process using the percolation model from theoretical physics. The main result of this analysis is that even for constituents showing irregular variations so that the concept of an effective age is inapplicable, the inversion problem of deducing an atmospheric history from measurements of gas concentrations in ice cores is more stable and less influenced by errors than most other inversion problems in atmospheric chemistry.

Reactive gases and aerosols

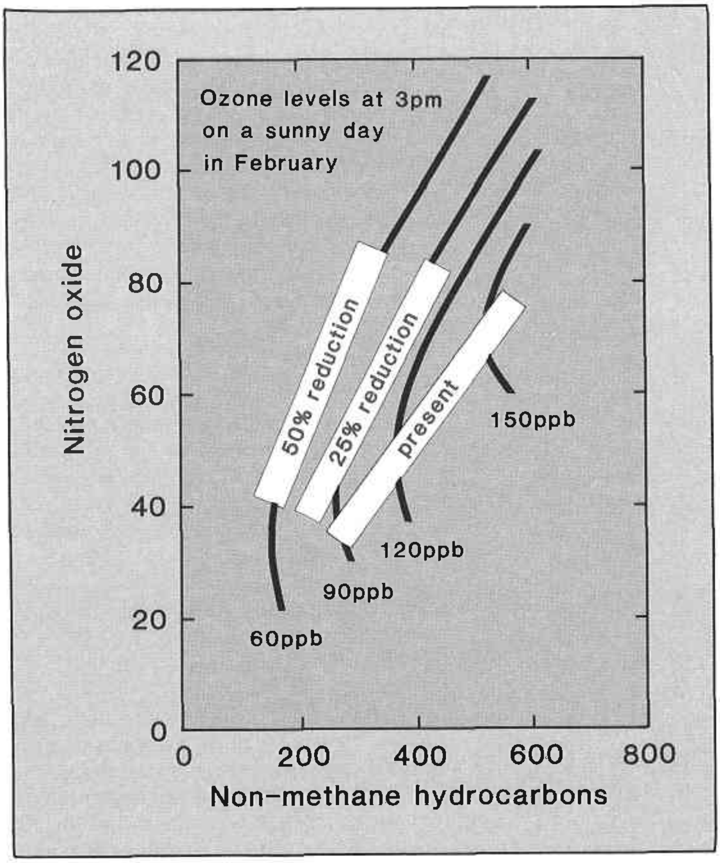
Some of the crucial problems of atmospheric environmental quality involve species that are rapidly transformed by chemical reactions within the atmosphere. Photochemical processes produce inorganic and organic acids that acidify rainwater in both polluted and unpolluted regions. These same photochemical processes produce particles that act as cloud condensation nuclei which can influence cloud properties, and particles that scatter light and affect visibility in the lower atmosphere. Within cities and in regional areas affected by pollution this photochemistry is involved in ozone formation and the generation of the "smog" which plagues large cities. The reactive species generally have a short lifetime in the atmosphere, and so a major influence on their concentration comes from the variability in their sources. Little or nothing is known about many of the natural sources, for example, biological production of trace gases and the production of carbon particles in natural wild fires. The research program of Reactive Gases and Aerosols involves the study of selected fundamental and applied research problems in these areas.

Urban and regional air pollution

Smog chamber studies of Melbourne's air

The occurrence of photochemical smog in Australian cities was first discovered by workers at Aspendale in the late 1960's. This work, which evolved through various phases, culminated in chamber studies of the photochemical processes during 1983–1985. These studies have now been terminated and a new initiative involving study of regional air pollution is starting in 1985/86.

The chamber study of photochemical ozone formation in Melbourne's air involved a novel concept for urban pollution studies. Characteristic trajectories were determined for air parcels that caused ozone air quality exceedences in the Melbourne Central Business District. The factors that influence ozone formation and which determine their variation along the trajectory pathway were examined. These factors included emission rates of nitrogen oxides and non-methanic hydrocarbons, solar radiation, air temperature and atmospheric mixing rates. After this information had been assembled a laboratory study was commenced where an air sample, conditioned



Smog chamber predictions of how ozone levels in Melbourne's smog episodes are expected to fall in response to 50% and 25% reductions in non-methane hydrocarbon emissions as a result of the fitting of catalytic converters to motor vehicles (concentrations in ppb).

to be representative of the air prior to dawn on a "smog" day, was placed in a "chemically inert" controlled environment chamber. There it was subjected to changes in UV radiation, temperature, addition of pollutants and dilution that simulated the influences on an air parcel as if it had been following the atmospheric trajectory over Melbourne. Thus chemical processes appropriate to the real atmosphere were studied in the chamber. This novel approach turned out to be very precise and it was found that chamber results were within 10% of those obtained when a fully instrumented aircraft was used to follow air parcels across the eastern suburbs of Melbourne.

The ultimate use of the chamber was to make predictions of the effects of reducing pollutant emissions into Melbourne's air. Needless to say, such an experiment could not be carried out in the real atmosphere except at enormous expense. In the previous figure we see the ozone levels formed in Melbourne's air for various observed levels of hydrocarbons and nitrogen oxides in the morning air. Also on this diagram, from the smog chamber studies, are observations of the ozone levels that would occur if the hydrocarbon levels were reduced to either 75% or 50% of their current levels due to the introduction of automobile emission controls. Thus the chamber studies provide essential information for regulatory action concerning hydrocarbon and nitrogen oxide air pollution emissions in urban regions.

This study was for air trajectories moving from the eastern suburban to the central business district of Melbourne. There are other trajectories around Melbourne that lead to "smog" events and these need separate study by this or other techniques.

Air quality in the Latrobe Valley

Subsequent to the work on urban photochemical pollution a joint study was undertaken in collaboration with the EPA, SECV and Siromath to investigate, through a combination of physical/chemical understanding and statistical analysis techniques, the causes of variations in ozone concentrations in the Latrobe Valley. More than 95% of the time the ozone levels in the Latrobe Valley reflect clean air as experienced at Cape Grim, Tasmania. However, the State Environment Protection Policy Ambient Air Quality Acceptable Levels for ozone are exceeded on occasions, and these exceedences are of concern to the responsible agencies. As a result of the joint study, areas of scientific ignorance pertaining to this regional air pollution were identified and a new initiative for work in this area taken.

Nitrogen oxides

Biological processes on earth have a major role in maintaining the composition of the earth's atmosphere in a state removed from that of chemical equilibrium. The most outstanding example of this is the presence of oxygen in the atmosphere which would not be there except for the presence of living photosynthetic organisms.

One of the other, lesser known, mechanisms in this category is the release of reactive nitrogen oxides by micro organisms to the atmosphere. During the aerobic microbial oxidation of ammonium to nitrite and nitrate in soils and water bodies, nitric oxide (NO) is released to the atmosphere where it plays a major regulatory role in tropospheric trace gas chemistry.

During 1983/85, in collaboration with workers at the University of Stockholm, the University of Melbourne, and the Divisions of Plant Industry and Irrigation Research, laboratory and field experimental studies and theoretical work has continued to unravel the mechanisms of nitric oxide release by micro organisms. Field studies have allowed the determination of the fraction of applied nitrogen fertilizer lost as nitric oxide while on the theoretical side an empirical model has been developed which incorporates biological, chemical and diffusive processes so that, from laboratory measurements, the soil to atmosphere fluxes of NO within the field may be predicted.

The role of these nitric oxide fluxes in regional air pollution is now being investigated.

Aerosols

Airborne particles

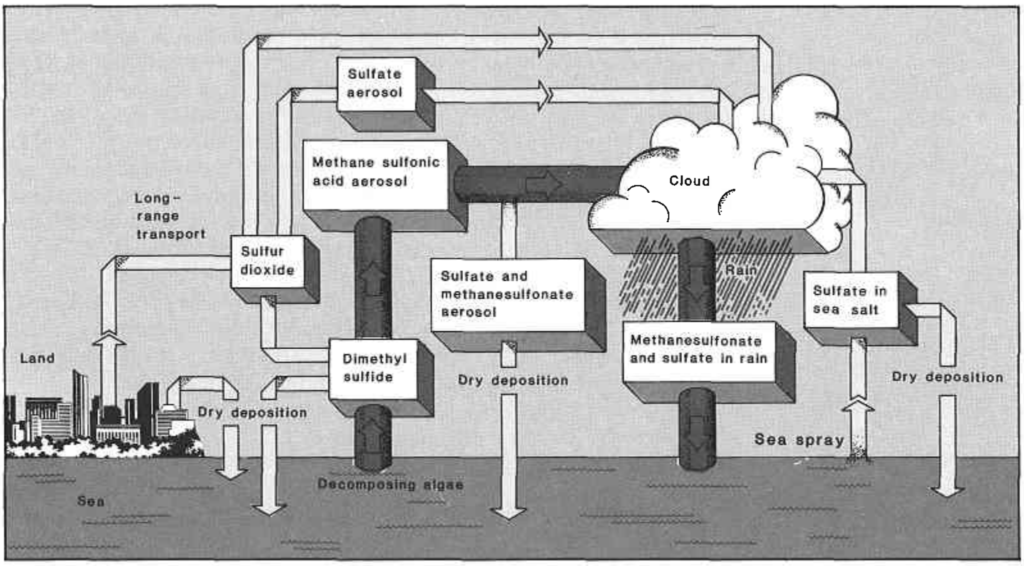
Recent work on airborne particles has included studies aimed at understanding the production and transport of natural particles at different levels in the troposphere in the Southern ocean area. This incorporates work done at the baseline monitoring station at Cape Grim and complementary programs at Mawson (Antarctica) and Macquarie Island. These programs have been supported and expanded by recent extensive airborne measurements of particles in the free troposphere around southern Australia. Several subsets of particles were included in these measurements; amongst them condensation nuclei, cloud condensation nuclei, ice nuclei, optically important particles and large hygroscopic particles. In cooperation with the DAR radiation group and the Western Australian Institute of Technology (WAIT) these airborne measurements have provided the first simultaneous determinations of microphysical and scattering properties of aerosol particles in the Southern Hemisphere. Other work has included studies of bushfire smoke properties in northern Australia and enhanced production of particles over the great barrier reef.

A recent shift in emphasis to more applied work has seen the commencement of a major study (supported by NERDDP) into the physical and chemical nature of particles responsible for periods of marked reduction in visual air quality in the Latrobe Valley in Victoria.

Sulfonates

One project concerned with particle production has involved the use of high-volume aerosol filters exposed on a monthly basis at Cape Grim since late in 1976. The filters were used to look for an aerosol component, methanesulfonic acid, which it was realised in 1983 might serve as an indicator of the relative contributions of natural (oceanic) and pollution sources to sulfuric acid levels in rain at Cape Grim. Pollution sources emit sulfur dioxide, which in the atmosphere is

The atmospheric sulphur cycle over the Southern Ocean. A major pathway (dark blue) links cloud formation with algae in the sea. Decomposing algae produce dimethyl sulfide gas, which turns into particles of methane sulfonic acid, which provide nuclei for cloud droplets to form around.



converted directly to sulfuric acid. On the other hand the ocean surface has recently been found to be a strong source of a biological decay product, dimethyl sulfide, which is also converted in the atmosphere to sulfuric acid but, it was thought, via the intermediate form of methanesulfonic acid. Since methanesulfonate is believed to be stable in the dry aerosol form, the many years of archived filters provided a unique means of assessing the presence or otherwise of methanesulfonate (and thus of a large natural source of sulfuric acid) in the aerosol. Nowhere else in the world was there a data set exceeding 1 year in length.

The filter analyses were carried out at the Australian Government Analytical Laboratories in Tasmania, one of whose officers acts as joint lead scientist for the Cape Grim rainwater composition program. Methanesulfonate was evident in all of the 104 filter samples analysed, but was found to have a distinct annual cycle in concentration. The concentration maximum occurs in mid to late summer, with concentrations averaging 10 times those of the winter minimum, and coincides well with the summertime maximum in biological productivity and decay expected of the ocean surface. This work clearly supports the idea of the ocean surface providing a large natural source of atmospheric sulfur, and of sulfuric acid in maritime rains. Work is now in progress to try and use this information to assess the relative importance of the ocean surface and other sources, including pollution sources, to the trace levels of atmospheric sulfuric acid found at Cape Grim.

Precipitation chemistry

Rainwater acidity in urban Australia

Two studies of rainwater acidity carried out over the Sydney and Melbourne region in recent years have now been concluded. They have shown that Australia's cities do induce extra acidity into weather systems moving across the metropolitan areas. However, the levels of acidity found are not high enough to be of immediate concern. Typical pH values found for Sydney are 4–5, and values for Melbourne are a little higher, 4.5–5.5.

Rainwater acidity in tropical Australia

In about 1980 a number of biological scientists working in the vicinity of the township of Jabiru and the Ranger Uranium Mine in the Northern Territory observed that fish in particular billabongs sometimes died in significant numbers at the commencement of the wet season. Their observations almost invariably indicated high levels of acidity and toxic levels of dissolved aluminium in the billabong water at the time of the fish kills. The coincidence of these factors with widespread mortality of fish is strangely characteristic of the deleterious effects of acidic rain on waterways in Europe and the U.S., and was one of the reasons behind a study of rainwater composition in the vicinity of Jabiru undertaken jointly by the Office of the Supervising Scientist (OSS) in the Northern Territory and the CSIRO Division of Atmospheric Research.

In the three wet seasons since 1982/83 rainwater has been collected at Jabiru East each time it rains. Samples are preserved against bacterial degradation by the addition of chloroform, and are analysed at the Jabiru East laboratories of OSS for pH, ammonia and dissolved metal concentrations. Anions are determined at CSIRO's Division of Atmospheric Research in Melbourne.

Results indicate that rainwater at the beginning of the wet season is indeed unusually acidic for a remote area far removed from large urban and industrial centres: pH values down to 3.5 have been observed from individual storms. Such values are as low as any yet observed in the heart of Sydney, and are comparable with values of 3.8–4.0 found in billabongs at the time of fish kills. However the anion analyses show clearly that the major rainwater acids are formic and acetic acids (acids found naturally in, for example, ant venom and vinegar), not the sulfuric acid that was evident in billabong waters and which is the major contributor to rainwater acidity in Europe and the U.S. In fact formic and acetic acids appear to be quickly consumed as a carbon source by common bacteria in the environment and so are unlikely to persist for long enough in soils or groundwater to cause acidity problems. The source of acidity in billabong waters appears to be quite natural — in the vicinity are found acid-sulfate flood plain soils. The reason for fish kills coincident with the first rains is that it is the initial input of water at the start of the wet season that raises the water table sufficiently for the sulfuric acid in the soil to be brought to the surface and washed into the billabongs.

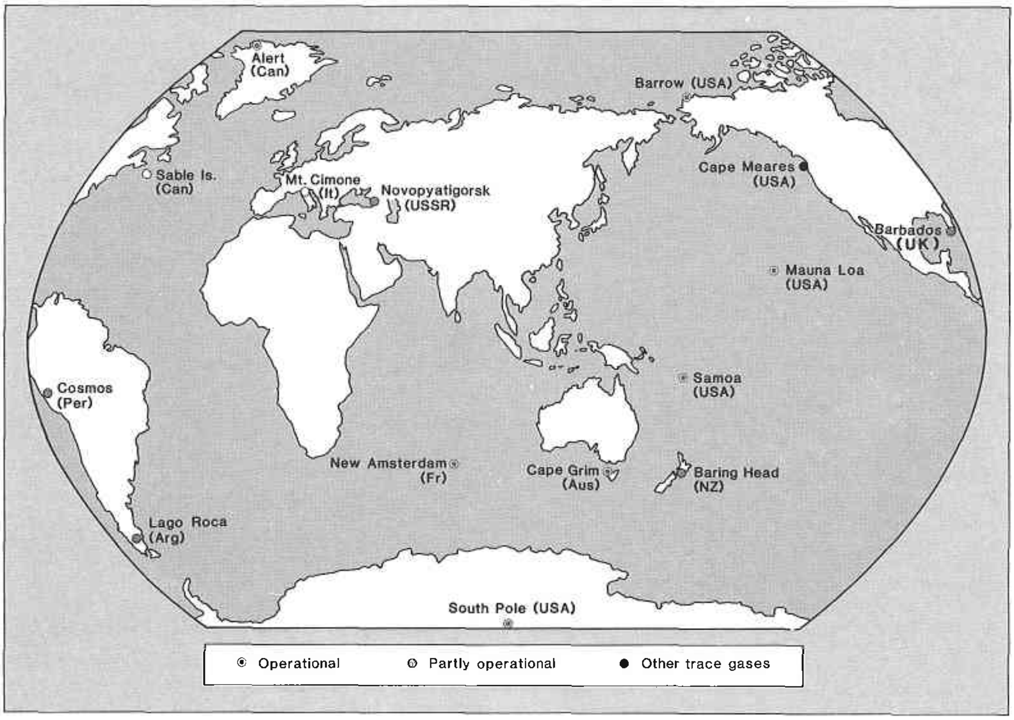
Studies on the origin of the newly recognised formic and acetic acids in Jabiru rainwater are continuing.

The Cape Grim Baseline Air Pollution Station

Operational since 1976, the Cape Grim Baseline Station is now well-established, and as well as providing quality background data, is proving a fertile area for research. The station fulfils an Australian commitment to the United Nations Environment Program, in which a global network of stations monitor changes in the global atmosphere. An overview of the current status of the global network is given in the illustration below.

During the 1983–1985 period, further developments have taken place in the management of CGBAPS. The station arose from a DAR/Bureau of Meteorology proposal in 1972. DAR scientists selected the location and developed the scientific program, with Department of Science and Technology funding. Joint CSIRO/Department of Science and Technology (now the Department of Science) management has continued, with the Department of Science management responsiblity transferring from the Analytical Sciences Branch to the Bureau of Meteorology in 1984.

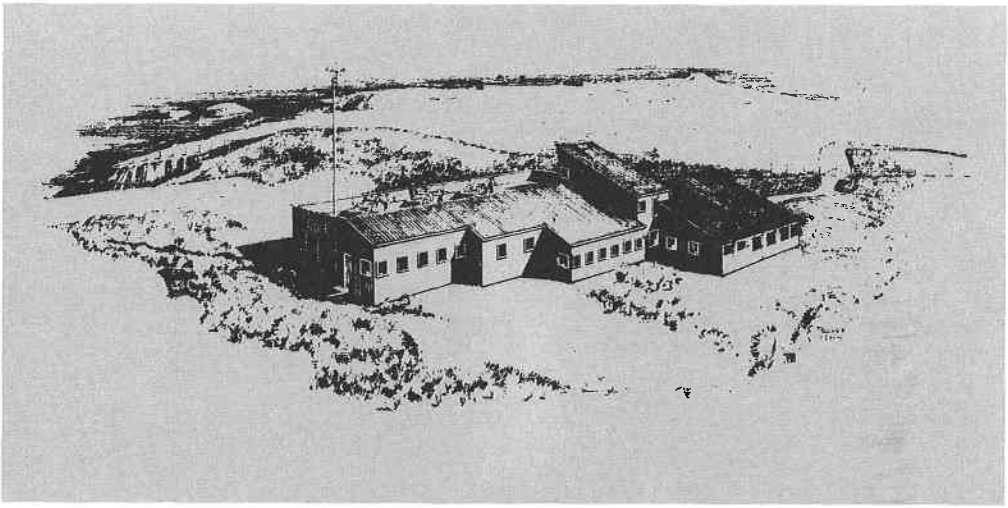
The global network of Baseline Stations where the background concentrations of atmospheric trace gases are measured.



Dr Roger Francey, of DAR, was seconded to the Department of Science and Technology and served as the Station's first Director from 1982 to 1984, when he was succeeded by Dr Bruce Forgan.

The measurement program at Cape Grim has expanded over the years and now includes almost all of the measurements originally recommended by WMO, plus some additional measurements (e.g. methane sulfonate) which directly address the WMO scientific objectives. The value of the Cape Grim observations is borne out by an increasing number of research papers which make use of Cape Grim data (summarised in the Station's biennial reports, Baseline 1981–1982, 1983–1984). A highlight in this respect was the international SABOAC (Scientific Application of Baseline Observations of Atmospheric Composition) Meeting held in Aspendale in November 1984. Some forty scientists from overseas attended; while the proceedings are being published as three special issues of the Journal of Atmospheric Chemistry.

The Cape Grim Baseline Air Pollution Station, Tasmania. The station is part of a global network of such stations which are used for observations of atmospheric trace gases in background air.



Clouds and radiation

Introduction

As it is the Sun which drives the Earth's weather machine, a precise understanding of the way solar radiation interacts with the Earth's atmosphere is essential to our knowledge of the physical basis of weather and climate. The research in the clouds and radiation group is part of an international endeavour to understand the processes that control climate, particularly those concerned with the fundamental forcing mechanisms of radiation. Clouds play a crucial role in modulating the radiation streams in the atmosphere and thus in determining the absorption of radiation within the atmosphere and at the Earth's surface.

Research consists of both theoretical and observational studies. In the former, emphasis is placed on fundamental properties of radiative transfer within the clouds and to a lesser extent, through atmospheric trace gases (e.g., carbon dioxide, methane, halocarbons). In the observational studies a number of remote sensing techniques are prominent, as well as direct aircraft studies in clouds. A well-established remote sensing tool is the Division's lidar (light radar) facility, which provides an excellent tool for cloud-studies and which also shows promise for environmental monitoring applications. A second, more recent, addition to the Division's remote sensing tools is the CSIDA (CSIRO System for Interactive Data Analysis) facility. This facility enables the acquisition and processing of remote sensing information from meteorological satellites.

The development of the CSIDA facility has set the scene for one of the directions of the research and development in the Clouds and Radiation Group in the years to come. The commercialization of CSIDA, as described below, is a pointer to the approach that will be taken to other developments in the field of high technology and remote sensing. This emphasis on commercialization will ensure that the benefits of newly developed techniques, processes or instrumentation will accrue to Australian industry.

In a move which may be seen as an extension of the CSIDA development (which deals with receiving and processing information gathered by satellite), some future research will be centred on the design and development of new instruments for remote sensing from satellites. A forerunner of this is the along track scanning radiometer, described below; other instruments are currently under consideration. All these developments tie in with the push for a greater involvement of Australia in the aerospace industry, promoted by the recently established **CSIRO Office of Space Science and Applications (COSSA)**.

Another important approach in the Clouds and Radiation Group is the study of cloud microphysics in situ. These aircraft studies using the CSIRO F-27 research aircraft involve studies of the radiation fields in and around clouds, and allow for direct measurement of microphysical properties of the clouds using instruments developed in the Division.

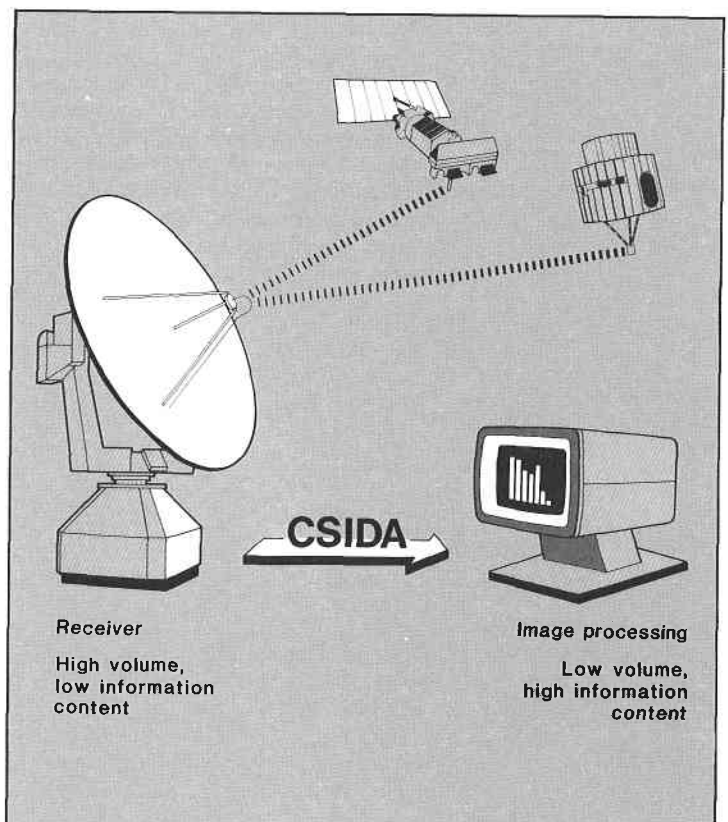
Satellite remote sensing

Studies of weather and climate depend heavily on observational networks which provide the basic information on the state of the atmosphere. Clearly, a major limitation of the information collected is the size and spread of the network — some parts of the Earth are very poorly covered. In recent years the atmospheric research community has come to rely more and more on remote sensing from satellites to provide data which would be impossible to collect in any other way.

Development of CSIDA

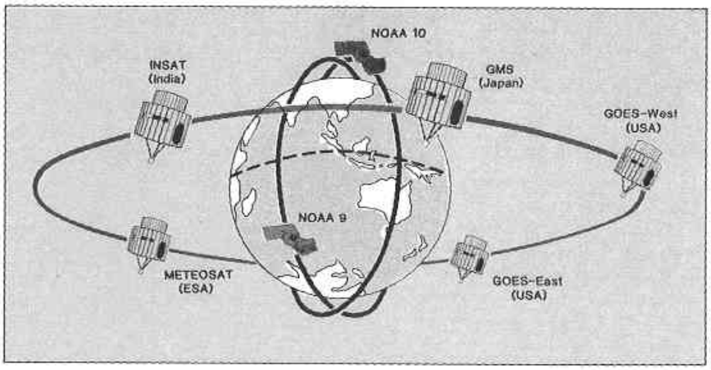
A major Divisional effort during 1983–1985 has been the development of the CSIDA facility. The facility was conceived as a research tool for atmospheric and oceanographic scientific investigations which would allow the scientists a 'hands-on' tool for real-time analysis of data collected by meteorological satellites. The decision to develop the facility rather than buy an existing one was based on the need for a system which makes use of the latest in software and hardware technology.

The central problem of satellite remote sensing in general, and of operational and research use of weather satellite data in particular, has become the *real-time* consolidation of vast quantities of low information-content data into small quantities of high information content data — quantities sufficiently small so that they can be comprehended easily by the user. In the context of satellites the process must involve equipment and computer techniques which are the ultimate in image handling and display and which can handle complete images as seen by satellite as easily as if they were single data points.



The essence of CSIDA is its capacity to reduce the large amount of low-information data beamed down by satellites to a small amount of easy to manipulate high-information data.

CSIDA is an overall system which addresses both problems. It consists of receiving hardware which can obtain the highest resolution weather satellite data; of computing hardware of sufficient power to handle the data at the enormous rates required for real-time analysis; and of display hardware which enables an operator to visualize scenes and images on colour TV monitors. More significantly however, it consists also of very modern image handling and data analysis software which places enormous power in the hands of the user for purposes of extraction, analysis and disposal of data.



A Southern Hemisphere perspective of the geostationary and polar-orbiting meteorological satellites. The geostationary satellites are in earth-synchronous orbit 36,000 km above the equator, the polar-orbiting satellites are in approximately north-south sun-synchronous orbits 800 km above the surface. The CSIDA facility currently receives images from NOAA-10, NOAA-9, and GMS-3.

The software

The basis of the software is the SLIP/DISIMP image handling package developed originally by the CSIRO Division of Computing Research in collaboration with the Australian company Quentron. To date 25 man-years have been put into developing the basic package, which consists of professionally written and fully documented software suitable for commercial sale and commercial maintenance. In that respect it is probably the most professional image handling package appropriate for satellite data available anywhere in the world. It is being continually updated, and includes as well the 5 man-years (to date) of development by the Division of Atmospheric Research which was required to tune the basic package for use with weather satellites.

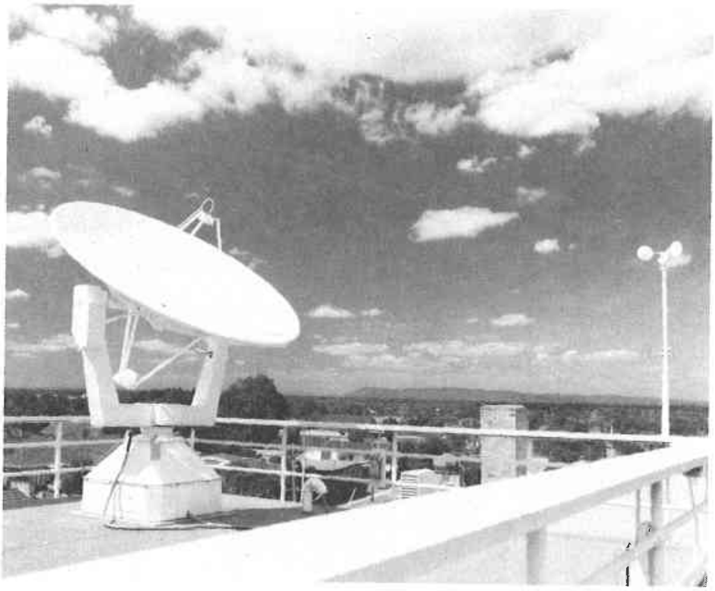
The package is 'menu driven' in that the operator can sit at his terminal, interrogate the computer for the options of what tasks he can perform on the imagery, and be led step by step through the necessary processes needed to do what he wants to do. Of necessity the menus are complex because the image handling package is very general in its capabilities. However, they are user-friendly and can be overridden by single commands to produce a particular result if the operator wishes.

The tracking antenna

The antenna for receiving information from the geostationary satellite is fixed, as the satellite does not change position, but the antenna for receiving data from the polar orbiting satellites needs to be able to track each satellite as it passes over Australia. The antenna which was designed and built by the Division's mechanical and engineering staff is now under commercial production by PCM Electronics Pty Ltd.

An image processing workstation

In 1985 the development of a stand-alone image processing workstation was commenced. Using the latest technology in electronics the image processing capabilities of the CSIDA system are being incorporated in the workstation which will be produced and marketed by the Dindima Group Pty Ltd.



The satellite tracking antenna, developed by DAR, on the roof of the Division in Aspendale. PCM Electronics Pty Ltd is now manufacturing and marketing the antenna for the Australasian market.

Applications

The applications of the image processing capability of CSIDA are many, both for research and for environmental monitoring. Examples run from cloud photographs supporting the Cold Fronts Research Programme and the clouds/radiation research programme, sea-surface temperature charts for oceanographers, rescue services and the fishing industry, to images of the Earth's surface for country fire authorities and the mining industry.

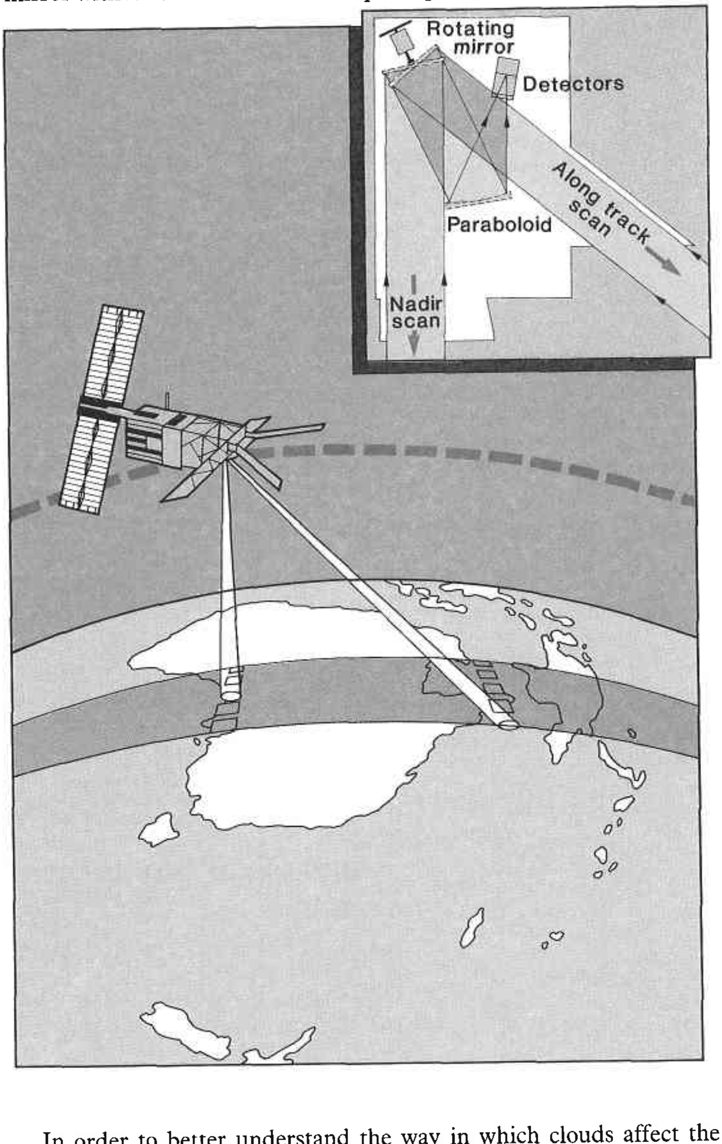
Sea surface temperature studies

Scientists in the Division are studying the use of satellite imagery from polar-orbiting satellites for the accurate determination of sea surface temperatures (SST's). Given the important relation between the dynamics of the Earth's oceans and atmosphere, an accurate method for obtaining SST information by remote sensing from satellites would be most desirable.

A major problem with the current technology of remote sensing using the AVHRR (Advanced Very High Resolution Radiometer) of the polar orbiting satellites is the need to correct the infrared reading of the SST's for the varying transmissivity of the atmosphere. Algorithms are being developed which will remove the effect of the atmosphere, thus leading to accurate SST's. As part of this process, there was a need for collecting 'ground-truth' data for comparison with the AVHRR readings from the satellites. For this reason a number of expeditions were held using the CSIRO research vessels Sprightly and Franklin, where SST measurements and radiosonde soundings of the atmosphere were carried out simultaneously with the collection of satellite images via CSIDA in Bass Strait and in the Coral Sea.

Along track scanning radiometer

The Division is contributing to the planning and design for a new European Remote Sensing satellite, the ERS-1. As part of the project design team DAR scientists have taken part in the construction of an Along Track Scanning Radiometer (ATSR). This instrument will be measuring radiation from the atmosphere and the Earth's surface at two distinct angles: directly beneath the satellite (its nadir) and at an angle ahead of the satellite (see illustration). By having a look at the same point on the Earth's surface (both land and oceans) along two distinct pathways through the atmosphere, the effects of the atmosphere on the signal received can be determined and removed. This will allow for very accurate remote sensing of information such as the sea surface and land surface temperatures discussed above. The nadir and forward scans are achieved by having a single rotating mirror with its axis offset from the optical path.

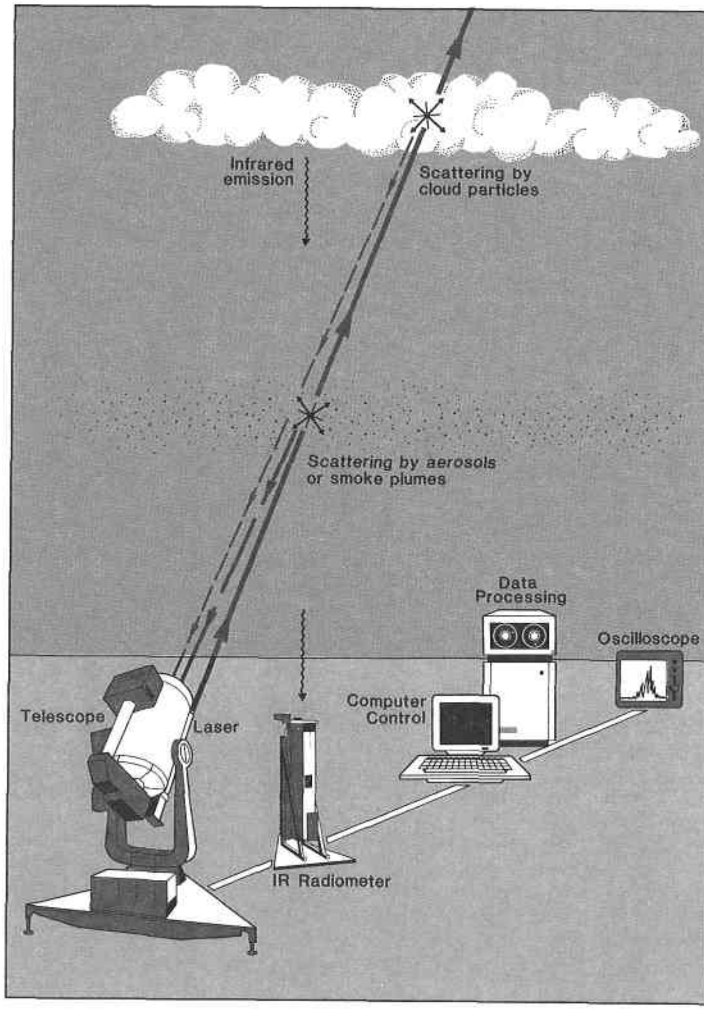


The ATSR instrument on ERS-1 will provide precise measurements of surface properties independent of the atmosphere through which these properties are measured. The key feature is the use of a forward scan in addition to the normal downward looking scan; the two radiometer readings, when matched for the same location below, allow corrections to be made for the intervening atmosphere.

Cloud/ radiation studies

In order to better understand the way in which clouds affect the Earth's radiation budget, detailed experimental (field) and theoretical studies are carried out on the interaction of water and ice clouds with radiation. Principal tools for such studies are the lidar instrument for remote sensing from the ground, the CSIRO F-27 research aircraft for direct observations in the air, and the CSIDA facility described above.

The lidar technique used for the remote sensing of cloud properties is also very suited to studies of aerosols and other particulates. A new infrared lidar, developed at the Division, is tunable and can be used to monitor gases in the atmosphere. Both applications are of great benefit to environmental studies.



A lidar (light detection and ranging) instrument employs a laser to send pulses of light into the atmosphere; an optical telescope is used to collect the light scattered by aerosols and cloud particles, and a data processing system allows the data to be analysed.

Theoretical and experimental studies of clouds

Studies of broken clouds in the boundary layer.

Theoretical studies carried out at Aspendale and elsewhere on broken cloud fields indicate that these cloud fields have very different radiative characteristics compared to equivalent 'extended' cloud sheets. Aircraft flights in 1983 and 1984 using a new CSIRO developed spectrally scanning narrow-beam radiometer for the 400 to 3000 nm region, the CSIRO narrow-beam 10–12μm radiometer and cloud microphysics equipment, obtained a considerable amount of data on broken cumulus fields and extended stratocumulus. These data have yielded detailed statistics on the spatial properties of broken clouds and are also providing information on radiances from broken clouds. A correlation of the solar reflectance and infrared emittance has shown patterns which are similar to those deduced from satellite radiances on quite a different spatial scale.

Two-dimensional Fourier transform analysis

Studies are being conducted to assess the value of satellite borne instruments which use Fourier transform analysis techniques to represent the spatial variability of non-uniform cloud decks.

Applications will include the use of such data in cloud climatological studies, and an investigation of the possibility of their use in numerical models of the global circulation.

Lidar studies of cirrus ice clouds

The radiative properties of clouds are very hard to treat in detail in climate or forecast models because the cloud properties depend on a number of factors such as the cloud liquid water content, temperature, particle type (whether water or ice crystal), particle size distribution and cloud structure.

Ideally, for inclusion in a predictive model, the cloud optical properties should be obtainable from parameters which can already be predicted by numerical models, such as temperature, or liquid water content. As these parameters are to some extent interdependent, there is a possibility of simple relationships if one averages over time, or space. Cirrus clouds are particularly hard to treat because they are composed of numerous ice crystal types and also because they are found to be very variable in total ice content.

In order to see whether, on average, simple relationships existed for cirrus optical properties, a large set of cirrus cloud data covering a year at Aspendale (midlatitude cirrus) and a month at Darwin (tropical cirrus) was obtained. This data set has since been analysed to obtained. This data set has since been analysed to obtain detailed information on cirrus optical properties and structure. In addition to the lidar, which gives information on visible properties, a passive

The Division's CO_2 and ruby lidars are now housed in a caravan, which enables the scientists to take them off the site for field expeditions. Recent expeditions were to Mildura (October, 1984 and July 1985) and to the Latrobe Valley (March, 1985).

infrared radiometer was used to measure the infrared emittance of the clouds. Although there were wide deviations from one cloud system to another, on average a very close dependence of infrared absorption on temperature was found.

As a check on the generality of this dependence, particle size distributions from field studies of cirrus clouds in the USA by U.S. scientists were also analysed and the extinction computed. The analysis demonstrated a very definite dependence of the particle size distribution and the extinction on cloud temperature. The average values of extinction gave a very similar dependence on temperature to the lidar data and the variability at a given temperature was related to the liquid water content which could be calculated from the particle data. An analysis of ice crystal replica data from the same U.S. study was also carried out to examine the small-particle end of the size spectrum which was not accurately measured by the optical particle counters. This end of the spectrum contributes about 50% of the extinction in the colder clouds. The replica tapes record single images of crystals, and many thousands of crystals were sized and counted manually. The average distribution was quite similar to that obtained by the optical particle counters, except for very small particle sizes. The ice crystal habits were also examined and classified. They showed crystal types which had not previously been seen in cirrus clouds.

The research has shown that the extinction in cirrus averaged over many cases is a function *only* of the cloud temperature, a result that is crucial for correct parameterization of cirrus radiative properties in climate models. For averages over shorter time periods, variability at one temperature can be calculated if the liquid water content can be predicted. The cirrus programme has also yielded much information on cloud structure, and on its formation and evolution.

Aircraft and lidar studies of middle level mixed phase clouds

The aircraft and lidar work was merged together in a study of middle level mixed-phase (i.e. both ice and water) clouds. As no previous information from simultaneous observations on cloud particles was available, the present observations represent a valuable data set. The data should be useful not only for investigating the climate properties of mid-level clouds but also by providing "ground truth" data for both the lidar measurements and for satellite radiance data which were collected as well.

Aerosol measurements

Lidar studies of wind

In collaboration with the small-scale dynamics group, the ruby lidar has been used recently for measurement of winds and turbulence in the boundary layer by using atmospheric aerosols (haze particles) as tracers. A programme is also being developed to measure the diffusion characteristics of smoke plumes emitted from power stations in the Latrobe Valley. These studies will contribute to the research carried out as part of the Latrobe Valley Airshed Study.

Infrared lidar studies of aerosols and pollutant gases

The infrared lidar developed in recent years at the Division is now equipped to scan automatically various laser emission wavelengths (60 wavelengths between 9.2μm and 11.4μm). It has been used initially to measure backscatter coefficients of atmospheric aerosols (haze) in conjunction with a NASA programme to develop a coherent lidar for wind measurements. An observational programme obtained relative values of infrared and ruby backscatter as well as direct sampling of particulates by aircraft (see atmospheric chemistry section).

The infrared lidar can also be used to measure profiles of atmospheric trace gases. Water vapour has already been measured to 1km altitude. It is planned to use it to measure profiles of other gases such as ammonia, ozone and ethylene. The techniques have commercial and industrial applications and there is close liaison with industry.

Climatic effects of natural maritime aerosols.

Vast regions of the ocean are covered by maritime haze aerosols and their optical properties depend on quantities such as wind speed and relative humidity. As part of the Division's study on baseline atmospheric conditions (see atmospheric chemistry section), the spectral optical depths of the maritime haze have been studied at Cape Grim over several years. The optical depths have been related to windspeed and humidity and the relationships are found to be rather similar to those found in other parts of the world. In fact, the clean haze maritime properties should be predictable to reasonable accuracy from windspeed and relative humidity alone.

Cloud microphysics

An important aspect of studies of clouds and precipitation is the detailed study of cloud microphysics. The radiative properties of cirrus clouds and the generation of lightning in thunderstorms are vastly different phenomena which are controlled by the microphysical constituents of the cloud, i.e. the sizes, shapes, and concentrations of the ice and water particles that make up the visible cloud. Most of the information concerning these particular cloud properties has been obtained through direct sampling from research aircraft, and CSIRO's F-27 has been an ideal platform for this type of research (see also the preceding section describing the use of lidar for cloud studies).

However, any aircraft penetration of a cloud disturbs the equilibrium position and concentrations of the particles, and researchers have known for some time that such disturbances could give rise to erroneous measurements, but have had no tools with which to gauge estimates of the magnitude of the problem. In the period 1980–83, the Cloud Microphysics Group obtained experimental data from the F-27 which suggested that the sampling problems were more serious than had otherwise been thought, and during the following two years embarked on a research program which essentially solved most of the major problems in this area (see discussion below).

The CSIRO F-27 research aircraft.

The F-27 research aircraft

The CSIRO research aircraft is a Fokker F-27; its operating speed in research missions is about 300 km/hr, its ceiling about 7.5 km and its endurance 6 hours, less the time equivalent of statutory fuel reserves, which may be from 0.75 to 1.5 hours according to weather conditions.

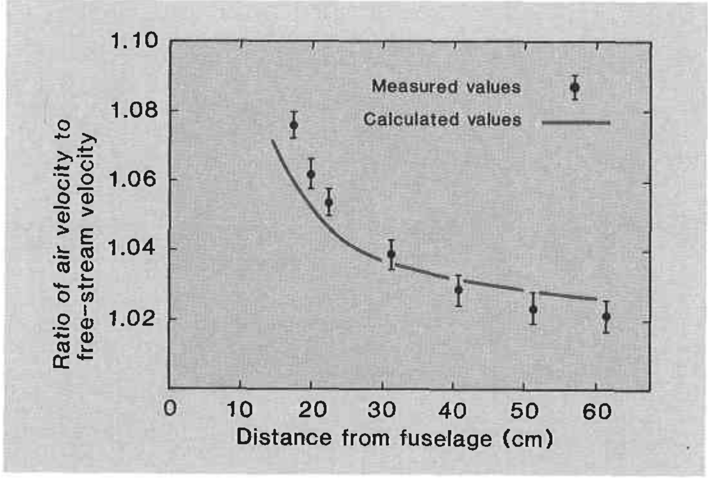
The aircraft is equipped with a computer controlled data acquisition system, and a wide range of instruments. Typical measurements include temperature (dry and wet bulb), pressure (static and dynamic), radiation, cloud water content and velocity, while in addition air samples and aerosols may be collected. The aircraft is also ideally suited for measuring aerosols and cloud particles using Knollenberg's one- and two-D particle probes. The F-27 research aircraft has been operational in CSIRO since 1979, replacing a DC3 which had been used for some 20 years for cloud physics research.

Airflow around aircraft

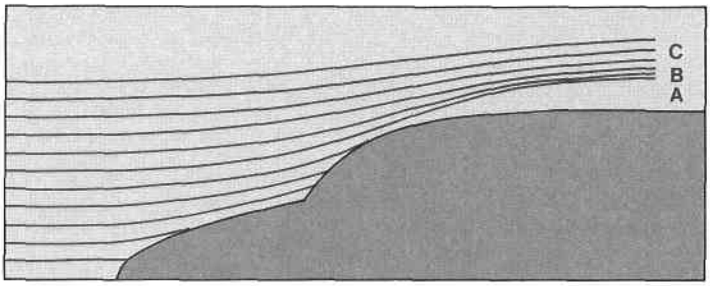
The starting point for any calculation of sampling errors lies in determining the airflow around the aircraft fuselage. One way to do this is to simulate the body of the aircraft using a distribution of convenient mathematical contrivances known as sources and sinks. The aircraft fuselage is simulated by placing a number of these sources and sinks in a stream. Because the strengths and locations of the required sinks and sources are unknown, the process is basically one of intelligent guesswork, aided by a few mathematical constraints.

Once the distribution of sinks and sources is known, the flow velocity at any point is calculated simply by summing up the inverse-square contributions from each of the sinks and sources.

The airflow calculations were then used to compute the trajectories of cloud particles which move around the aircraft fuselage and wings, and the illustration below shows how severe the sampling problem can be for 100μm droplets moving at 90ms-1 around the F-27. An examination of many of these trajectory computations together with some physical scaling has led to dimensionless curves of the type shown in the diagram below, which allows the findings to be applied to aircraft of different shapes and sizes flying at a range of speeds and altitudes and sampling particles of diverse shapes, sizes and densities. These curves were verified experimentally using data obtained from specially designed instruments which could be moved in and out from the F-27 fuselage.



A comparison of measured values of air velocity with those calculated from a sink-source model of the F-27 fuselage (see text).



Calculated trajectories of 100μm water drops moving around the forward section of the F-27 fuselage. At location A no drops will be sampled, whereas at B the concentration of drops is in excess of the free-stream concentration at location C.

Other work of this nature concerned an analysis of data obtained by the National Center for Atmospheric Research in Boulder which showed a preferential spatial concentration of ice columns as sampled by underwing opto-electronic probes. This re-orientation of randomly spread columns was shown to be caused by vortices which exist at the tips of wings as a consequence of the lift they generate. Calculated orientation angles agreed with the measured ones to within a few degrees, and the analysis has shown how the re-orientation effects can be allowed for in the data analysis.

Small-scale dynamics

Introduction

Direct manifestations of "weather" such as winds, storms, cold fronts, and the effect of the local wind field on air pollution problems, are all due to the behaviour of the boundary layer of the atmosphere. Studies of this boundary layer are aimed at improving our understanding of the way the lower atmosphere responds dynamically to the fields of heating and cooling which occur as a result of incoming solar radiation and outgoing terrestrial radiation.

The research combines theoretical analysis with numerical *modelling* and laboratory experiments (geophysical fluid dynamics), while important information to support this work is gathered during field studies. Thus, the main objective of the research described in this report is to improve our understanding of the dynamics of selected small scale atmospheric phenomena, and of their interaction with, and forcing by, the large scale atmospheric environment and the Earth's topography (including the coastline and hills).

A new project which will be additional to the current research effort from 1985/86 will be research on bushfire meteorology. Scientists in the small-scale dynamics group will be working with members of the National Bushfire Research Unit (NBRU) of the CSIRO Division of Forest Research. The objective will be to improve our understanding of bushfire meteorology and fire-plume dynamics.

The focus of the research effort in the small-scale dynamics group involves the Cold Fronts Research Programme (CFRP), the Latrobe Valley Air-shed Study (LVASS) and the associated Plume Tracking Experiment (PTE) and, in future, activities of the NBRU. Our research projects cover mesoscale processes (local and regional weather), environmental dynamics (problems related to air pollution) and bushfire related work. There is considerable collaborative work with the newly established Bureau of Meteorology Research Centre (BMRC), the State Electricity Commission of Victoria (SECV) and the Universities.

The research described in the following sections is organised into the two principal sub-programs: mesoscale processes (sea breezes, cold fronts), and environmental dynamics (air flow in valleys, flow over topography, turbulent dispersion).

Mesoscale processes

A study of atmospheric phenomena on a scale intermediate between large scale (synoptic) and small scale (boundary layer), directly relevant to local and regional weather (horizontal scales 10–500 km).

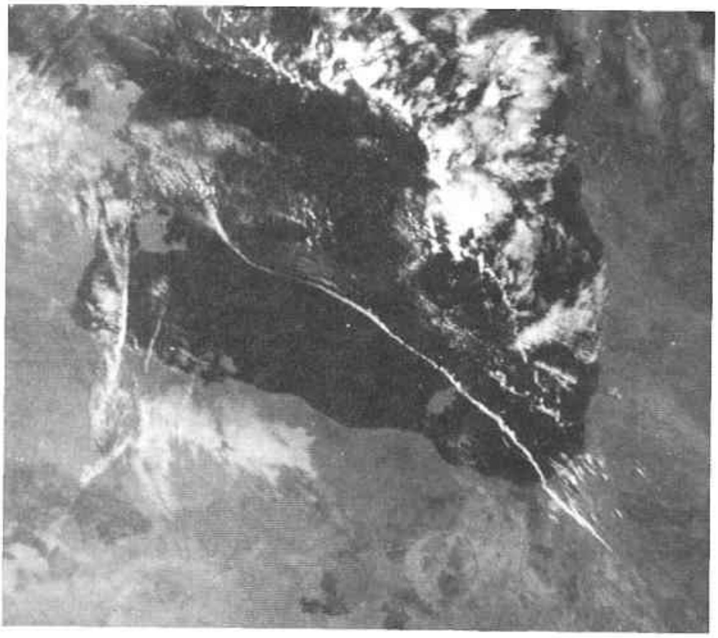
Tropical sea breezes

Our studies of tropical sea breezes were stimulated by two field experiments in the Gulf of Carpententaria region: the Morning Glory experiments of 1979 to 1983 organized by Monash University and centred at Burketown and the earlier Koorin experiment (1974) centred at Daly Waters, described in previous reports. The studies were supported with results from a two-dimensional mesoscale model.

The Morning Glory

A highly ageostrophic flow and a shallow surface-based stable layer beneath a deeper neutral layer are invariably observed at Burketown on the morning following a sea breeze. These conditions are ideal for the propagation of an undular bore (known as the 'Morning Glory') which is generated at the Cape York Peninsula to the northeast and observed at Burketown in the dawn hours. The mesoscale model reproduces well the strong nocturnal circulation and deep inland penetration and the model wind and temperature profiles in the early hours in the coastal region show that the sea breeze is responsible for the observed conditions for bore propagation.

Application of linear internal wave theory to observed early morning profiles with and without sea-breeze effects indicates that both profiles will support waves propagating at speeds within the observed range for morning glories. However, the typical pre 'glory' profile of a deep neutral layer overlying the low-level stable layer, a situation necessary for the trapping of wave energy in the low levels, is rarely observed on non-sea breeze occasions. The more common situation of marked stability aloft is probably associated with synoptic-scale subsidence.



The 'Morning Glory' over the Gulf of Carpentaria as observed by the NOAA-6 meteorological satellite on 24 October, 1984, at 7.19 a.m., Australian eastern standard time. The image was received and processed by the Division's CSIDA facility.

Koorin

Observations from this field experiment were used with the mesoscale model to study the nature of the inland boundary layer at low latitudes in terms of the nocturnal jet and sea-breeze influences. In the experiment (one month long) geostrophic winds were in the range 10-20 ms-1, and ageostrophic winds well above the very rough surface were about 5-10 ms-1, with cross-isobar flow angles of about 40. Nocturnal jet development by midnight was probably the result of these large ageostrophic winds, strong surface cooling and favourable sloping terrain. Initial development was certainly aided by rapid decay of turbulence aloft, itself produced by strong radiative cooling of the air.

At around midnight, or even earlier, further jet development was prevented by apparent sea breeze activity; this occurred some 280 km inland from the coast and was supported by two-dimensional model sea-breeze simulations. This sea-breeze activity occurred in conditions of strong onshore and along shore geostrophic winds not normally associated with such activity. Overall the sea-breeze manifested itself at Daly Waters, and in the model, as a cooling in a layer 500–1000 m deep, with an associated surface pressure jump, a strong backing of the wind and, when an offshore low-level wind is present, a collapse in the nocturnal jet.

Both the observations and the model results illustrate the extent to which sea breezes may travel inland (with penetration up to 500 km), and support work elsewhere that the sea breeze behaves as an unsteady gravity current.

Latrobe Valley sea breezes

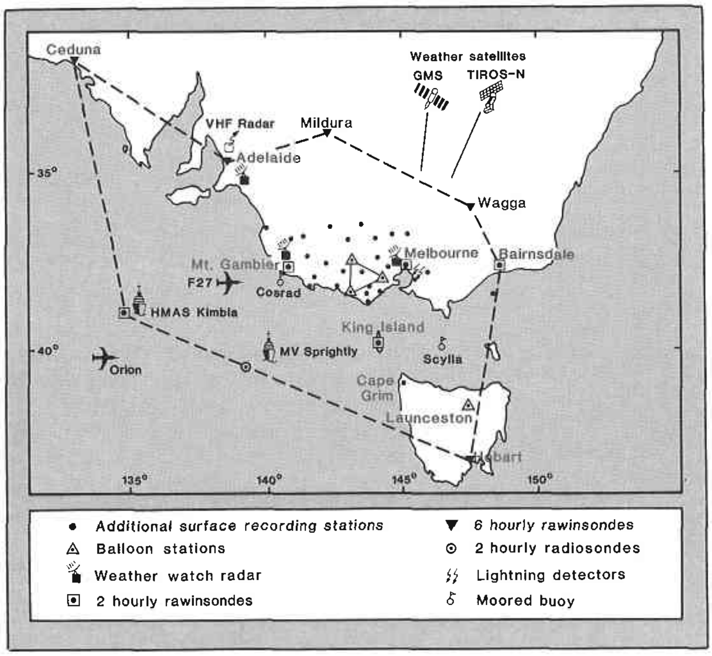
Analysis of surface and upper air data from five consecutive days of a weak northerly surface pressure gradient in the Latrobe Valley region has revealed remarkably regular behaviour in the mesoscale wind field. The observed diurnal cycle is triggered each day by a sea breeze from the east coast which reaches Trafalgar (100 km inland) around 1830 EST. As it advances up the valley, the sea breeze replaces westerly winds, from the surface to 1000 m, by easterlies. Above this level, the return flow combines with synoptic northwesterlies. Easterlies continue throughout the Valley during the night, gradually being replaced from above by westerlies which reach the surface around 1100 EST. The cycle then repeats itself. In the upper reaches of the Valley, this behaviour is modified by a sea breeze from the south coast entering the Hazelwood area via the Boolarra gap.

Research on cold fronts

The Cold Fronts Research Programme

The summertime cool change is an important meteorological phenomenon in southeastern Australia and frequently constitutes a difficult forecasting problem. In 1980 and 1981, the CSIRO Division of Atmospheric Research, the Bureau of Meteorology and several Universities carried out Phases I and II of the observational component of the Cold Fronts Research Programme. As a result of these two field studies a conceptual model of the "cool change" has been developed. Phase III took place between 14 November and 12 December 1984. The aim of Phase III was to further test the validity of the model. Phase III was the largest meteorological field study held in Australia and had the support of all the major meteorological research institutes in Australia as well a logistical support from the armed forces and several government instrumentalities. The extensive Phase III network is shown below.

The Division of Atmospheric Research participated in Phase III through the involvement of the CSIRO F27 research aircraft, and the design, installation and data analysis of a detailed mesoscale surface



The Observing network for Phase III of the Cold Fronts Research Programme.

network between Mt Gambier and Melbourne, and through collaboration with Melbourne, Monash and Flinders Universities operating the pilot balloon stations. In addition, satellite images from the NOAA polar orbiting satellites were recorded by the Divisions' CSIDA Facility. During the observational period, four frontal systems were observed. Detailed analysis of the data collected during the passage of these systems has commenced.

Conceptual model

The conceptual model suggests that the speed of movement of the frontal transition zone and the inflow of moisture and energy into this frontal transition zone are controlled by the synoptic scale flows. The model shows three distinct air streams. The first and most important is a warm belt of moist ascending air ahead of the front. The ascent cools the air in the frontal transition zone which in turn produces the cloud and associated thunderstorms. Behind the frontal transition zone cooler and drier air is descending. Above these two air flows there is a region of weakly ascending air.

The mesoscale structure within the frontal transition zone is complex. The model shows that the cool change may be heralded by a sea breeze, following which there are several change lines of varying severity (a change line is a change in the wind or temperature and is associated with a fall or jump in pressure).

Currently scientists in the Division are involved in a program to show that airborne observations interpreted with the aid of the conceptual model of the cool change coupled with satellite observations can enhance the quality of analysis over the ocean. In particular, the aim is to show that the technique is useful in identifying change lines that may move from the sea onto the land on days of severe bushfire risk.

Atmospheric gravity currents

a. Pre-frontal squall lines

Pre-frontal squall lines in summer produce a cold-air outflow as a result of evaporative cooling. This outflow may be 1-2 km deep and produces a pressure jump and wind-shift line similar to that produced by the shallow, dry cold fronts (known as cold surges) common to the region in late summer (a good example being the 1983 Ash Wednesday front). Movement of the pressure-jump line (at the leading edge of the cold air) depends on the gravity-current nature of the cold air flow, the environmental winds and, in the case of a squall line, on the squall-line motion as well.

In general, observations support a well-known relation for C_1, the gravity-current speed ($C_1 = C_\star + 0.7\ V_o$, $C_\star$ being the velocity of a gravity current in an atmosphere at rest and V_o the head or tail wind), modified, in the squall line case by V_s, the squall-line speed, according to

$$C = C_\star + 0.7\ (V_o + V_s)$$

b. Low level wind response to mesoscale pressure systems

The squall line and pressure jump line are associated with mesohigh and mesolow pressure features. Observations show a strong correlation between the behaviour of mean-surface and boundary-layer winds (e.g. rotation) and the passage of mesoscale pressure systems; the latter produce locally large horizontal pressure gradients.

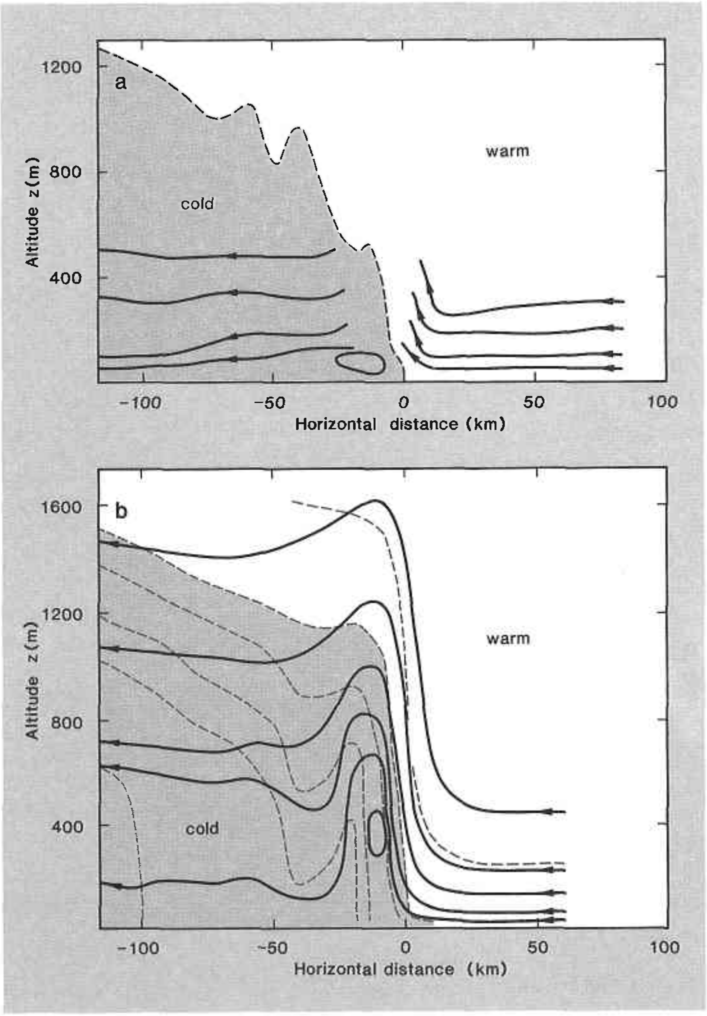
In one study, wind observations were simulated in a one-dimensional model by specifying a time sequence of perturbation pressure gradient and subsequently solving the vertically integrated momentum equations. Very good agreement was found between calculated winds and observations — in particular: a 360° rotation in wind on passage of the mesoscale high; wind-shift lines produced dynamically by the pressure-jump line; and a rapid linear increase in wind speed on passage of the pressure jump.

The understanding of winds in a frontal region is important so far as the short-term prediction problem is concerned. Without an appreciation of the dynamical relation discussed above, and the influence of mesoscale pressure systems, wind observations widely separated in time might be dismissed as being anomalous in the context of some preconceived model (e.g. steady backing of the wind on passage of a front).

c. Numerical simulation of atmospheric gravity currents

Simulations of two shallow cold fronts (cold surges) including that of Ash Wednesday 1983, demonstrate the unsteady nature of gravity currents (cold surges) where the flow tends towards a horizontal vortex structure, with zero flux of cold air towards the front. Flow seems to be almost everywhere through the front, from warm to cold, though this is possibly the result of limited horizontal (or time) resolution (see Illustration).

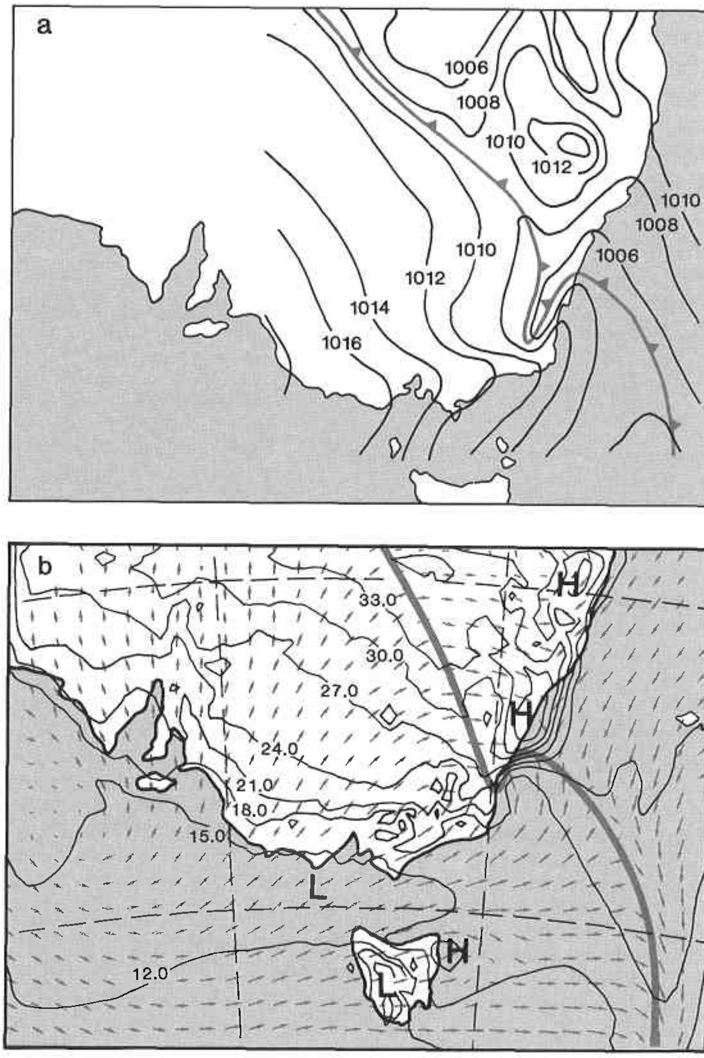
Further work under way includes investigations of the complete life cycle of an atmospheric gravity current, and studies of the influences of environmental shear and stability, surface characteristics and the Earth's rotation (viz. latitude) on gravity currents.



Cold Fronts: Experimental observations vs theory. a) Relative streamlines through the cold front of 16 February, 1983; winds were observed with an acoustic radar at Point Cook near Melbourne. b) A two-dimensional simulation of the same cold front using a numerical mesoscale model. Full lines are relative streamlines and dashed lines are potential temperature.

Coastal effects of the Southerly Buster

Three-dimensional numerical simulations using the NCAR-PSU mesoscale model have been performed on the 1 December 1982 Southerly Buster event. The work was undertaken in response to data collected during the Southerly Buster Observational Programme (SUBOP) which was organised on an informal basis between CSIRO, the Bureau of Meteorology and Monash University. "Southerly Buster" is the colloquial name given to intense squally wind changes that often occur along the coastal regions of New South Wales. The phenomenon is usually associated with the passage of cold fronts during the late spring and summer months. It is a widely held view that the Southerly Buster is an orographically induced disturbance forced by geostrophic adjustment of the blocked low level cross-mountain flow, although numerical simulations have revealed that alternative mechanisms exist, including differential land-sea friction and heating, which can lead to coastal trapping. Data collected during SUBOP have shown that this phenomenon should be regarded as a free-propagating, unattenuated front whose evolution is largely controlled by internal, mesoscale and small-scale processes. It is not wholly controlled by synoptic fields, and therefore escapes routine weather prediction techniques.



Southerly Buster events : experimental observations vs theory. a) Observed mean sea level pressure chart at 3 p.m. EDST, 1 December, 1982. b) Simulated surface winds and temperature field at the same time. The numerical simulations commenced at 9 a.m., 30 November.

The numerical simulations are directly relevant to an emerging study on coastal *channelling or trapping* of a cold front. This can occur in the absence of orography, may occur in Southern Victoria and can be demonstrated in terms of a north-south oriented gravity current representing a summertime cold front approaching an east-west oriented coastline. Rapid heating of post-frontal cold air over the land, and slow cooling of pre-frontal warm air over the sea, produces a north-south variation in cross frontal thermal contrast which has the effect of initially accelerating the front in the coastal region, and thereby producing the coastal channelling. Some idealized three-dimensional mesoscale model experiments are planned.

Reduction of observed pressure to mean sea level

During the mesoscale pressure analysis of the CFRP observations over Southern Victoria, we found such analyses in pre frontal and frontal passage situations to be particularly susceptible to the calculation of air column temperature required in the pressure reduction process. Over elevated, variable terrain in summertime, large errors in the pressure field can result if mean monthly temperatures are used (as is current Bureau of Meteorology practice in regional and synoptic analysis) rather than actual screen temperature (they may differ by 20°C or so). Thus, in Bureau of Meteorology analyses, the often observed high pressure ridge (ridging from the east), over the Great Dividing Range in summertime with north and northeasterly winds is an artefact of the errors arising from the use of such inappropriate temperatures.

Tornado-vortex simulations

A number of misconceptions concerning the role of the boundary layer in determining the maximum strength of atmospheric and laboratory vortices appear to exist in the literature. In order to resolve some of the problems, a number of sensitivity simulations have been performed using an axisymmetric numerical vortex model driven by an imposed bulk vertical body force which is intended to represent the main cumulus updraft of a storm. The model has been run for various values of applied ambient tangential velocity and turbulent eddy viscosity for both free and no-slip lower boundary conditions. The results show that for small applied tangential velocities, the vortex obtained using the free-slip condition is more intense due to greater frictional losses in the equivalent no-slip case. For large applied tangential velocities, the no-slip vortex is considerably stronger due to intense convergence of swirling air associated with a frictionally induced radial inflow jet in the boundary layer. The flow is very sensitive to the precise value of the turbulent eddy viscosity with vortex breakdown associated with the breaking of large amplitude centrifugal waves and quasi-steady toroidal vortices being a common feature.

Environmental dynamics

Studies of the atmospheric boundary layer and the interaction of the local windfield with topography, with special emphasis on the effect local atmospheric conditions have on the dispersal of air pollutants.

Latrobe Valley Airshed Study

The research of the small-scale dynamics group has for a number of years included detailed studies of the meteorological conditions in the Latrobe Valley. In the 1960's and 70's the Valley has been the centre of extensive industrial development, mainly due to the presence of vast quantities of brown coal, which forms the basis for Victoria's electricity generating industry. The question of the impact of such development on the air quality in the Valley has been the subject of study for scientists of the SECV, the Environment Protection Authority of Victoria (EPAV), the Latrobe Valley Water and Sewerage Board and the Division of Atmospheric Research. Included in DAR's research is the study of Latrobe Valley sea breezes (see above), plume tracking experiments and numerical modelling of the windfield in the Valley.

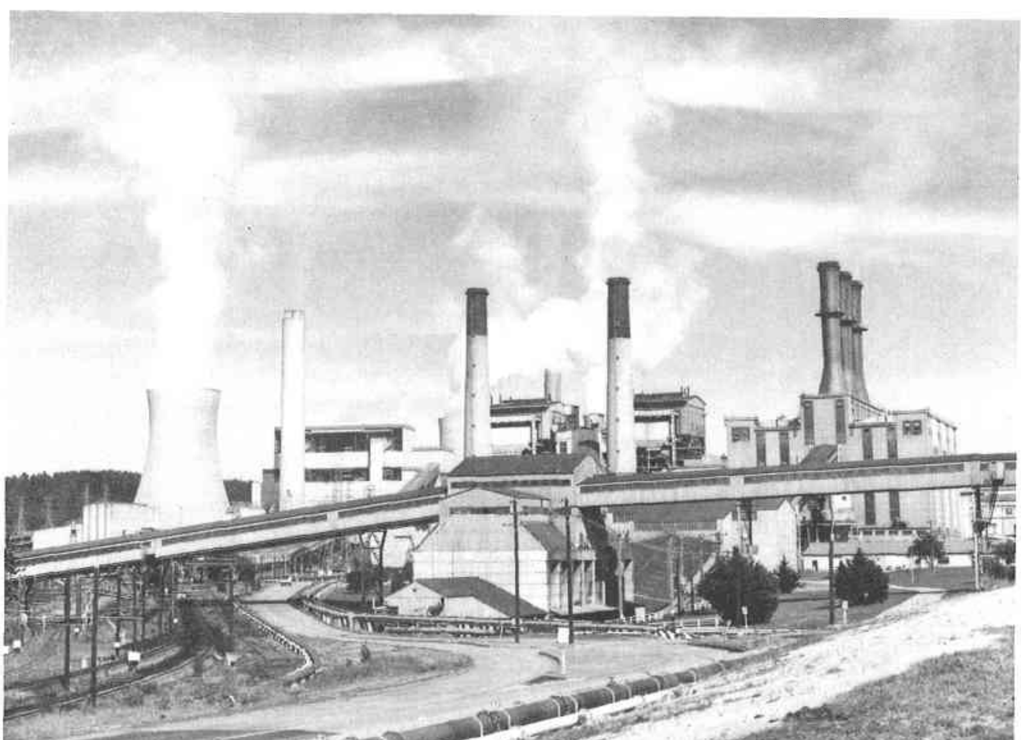
Plume tracking experiments

The Division's continuing involvement in the LVASS has been extended in particular to the NERDDC-funded plume-tracking experiment running over two winter and two summer campaigns commencing August 1984. During these campaigns the normal LVASS meteorological network is augmented by extra upper-air soundings which permit a detailed analysis of mesoscale wind fields. During the 1984 winter campaign several distinct mechanisms by which local and regional scale topography influence wind patterns were identified and studied by analyzing differences between winds measured at 1000 m and 100 m above ground level.

Under conditions of strong post-frontal winds when the upper-level wind tends southerly from westerly, low-level winds tend to continue to blow from the west along the axis of the valley. This phenomenon, Known as channelling, has also been studied numerically (see opposite illustration).

When the gradient wind at 1000 m is northwesterly, the flow in the valley changes markedly throughout the day. Early in the morning, winds are light and the air strongly stably stratified. Winds below 100 m are backed 60–90° and have an easterly along-valley component. This behaviour is a form of lee eddy and has also been reproduced and studied in laboratory towing tank experiments. During the day, as solar heating mixes the surface and upper air, winds in the valley strengthen, initially taking up the upper level wind direction but later over-shooting it to become channelled with a

Power stations in the Latrobe Valley. The way in which local topography interacts with the air flow in the Valley and hence affects local air quality has been the subject of the Latrobe Valley Airshed Study.

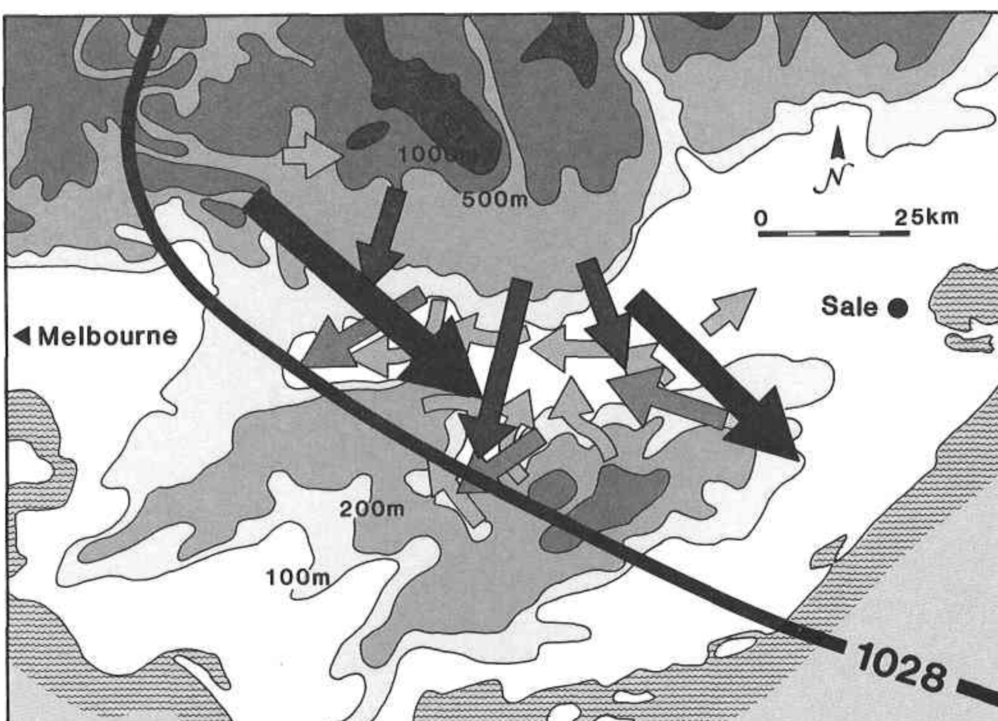


westerly component along the valley axes. The transition from lee eddy formation to channelling is controlled by the Froude number, $F = U/Nh$, where U is the wind speed at 1000 m, N the buoyancy frequency of air near the surface and h the terrain height above the valley floor. Numerical studies of these processes are in progress.

Mesoscale wind field model

As explained in the previous paragraphs, flow over complex terrain produces mesoscale phenomena (10–500 km length scale), where even broad details of the behaviour can not be resolved by the usual synoptic scale network. As mesoscale wind systems generated both by orography and by its perturbations of the synoptic scale flow are common, it is important that the fundamental dynamics be understood. A high resolution primitive equations model is being constructed to carry out numerical modelling studies of these problems. For the study, a sigma coordinate, staggered grid, hydrostatic representation has been chosen. Initial usage of the model will be directed towards case studies for the Latrobe Valley region, in particular using the dense low-level data provided by the plume tracking experiments. Because of the fine mesh sizes envisaged, with a corresponding requirement for small time steps, it has been considered necessary to produce a highly efficient set of vectorized algorithms to run on the CSIRO Cyber 205 computer. In the longer term it is likely that the model could be run in conjunction with an air pollution model to provide short term forecasts of air quality conditions for particular regions.

Interaction of topography and the geostrophic wind in the Latrobe Valley. The diagram shows how much the winds at various heights differ from the overlying geostrophic wind. Shown is the situation at 8 a.m., 15 June, 1984. There were fogs at low levels throughout the Valley, and deep stable air to 300m. Black arrows: 1000m winds; dark blue arrows: 300m winds; medium blue arrows: 100m winds; light blue arrows: 10m winds.



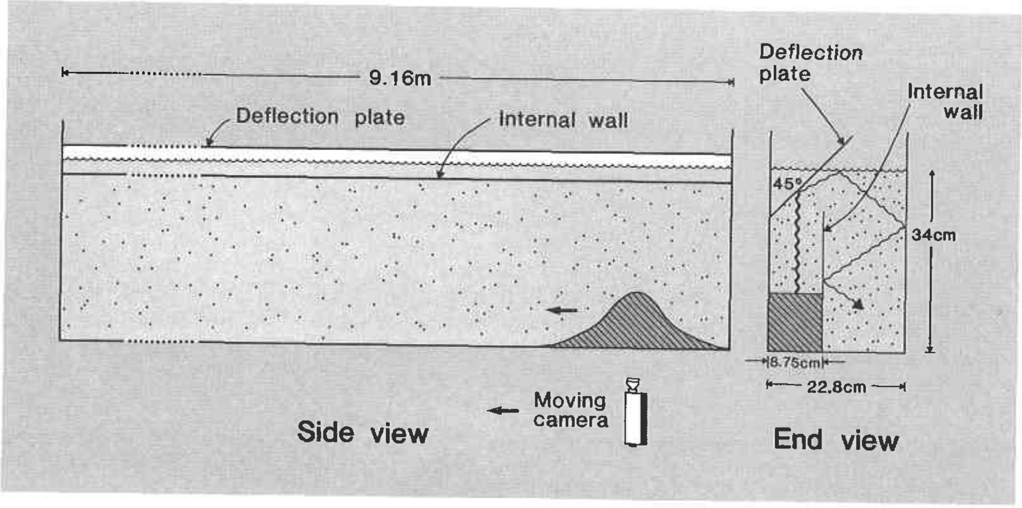
Flow over topography

Blocking in stratified flows

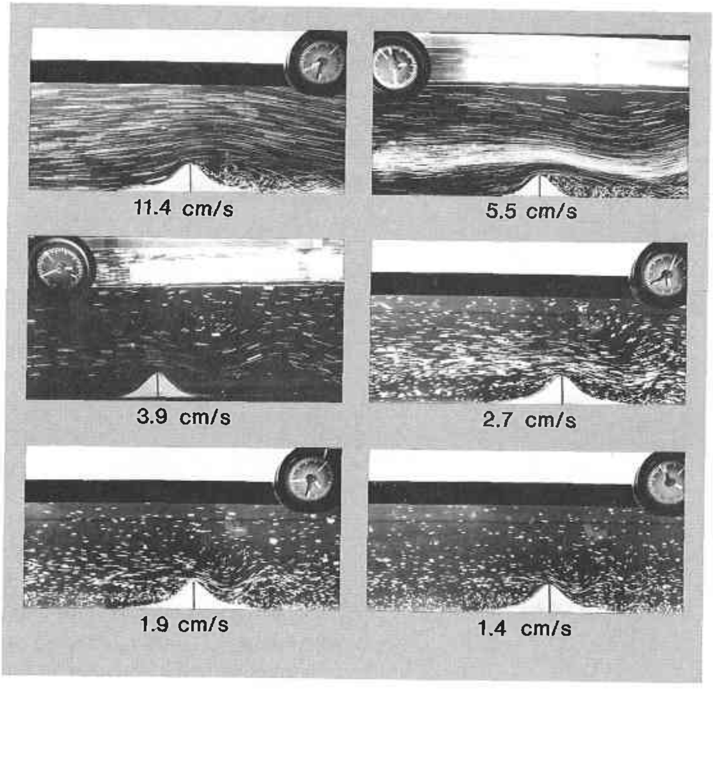
Work is continuing on laboratory and theoretical studies of the non-linear character of stratified flow over topography and the nature of blocking. A novel experimental technique which models a radiating

The experimental arrangement for simulating flow over topography in a fluid of 'infinite depth'. Shown are side-on and end-on views of the long tank in which the towing experiments are carried out.

upper boundary condition in a stratified fluid, simulating the atmosphere, has been exploited to investigate its effects on topographic phenomena. Through these experiments, it has been established that upstream blocking by two-dimensional obstacles in stratified flows is a wave-phenomenon, controlled by non-linear aspects of the flow over the ridge. In many situations the extent of this upstream blocking and other associated upstream effects can now be calculated, and the similarity between flows in the atmosphere and the flow over, for example, a ridge in a river has been delineated.



The illustration below shows upstream blocking and non-linear features such as a wave-induced 'critical layer' or stagnant region over the obstacle, with the realistic upper radiation condition modelling the atmosphere.



Streak photographs taken towards the end of experimental runs, using a bell-shaped obstacle. Towing speed as indicated.

Blocking in geostrophic flows

A collaborative study with Professor P. Rhines from the University of Washington, Seattle, is in progress. The possibility of applying the techniques used for the blocking studies in stratified flows to larger scale geostrophic flows over topography in the ocean and atmosphere governed by potential vorticity conservation is being explored with theoretical studies and laboratory experiments.

Previous studies on the nature of internal waves in submarine canyons were concluded with a study on the effects of the Earth's rotation on such disturbances.

Airflow in valleys

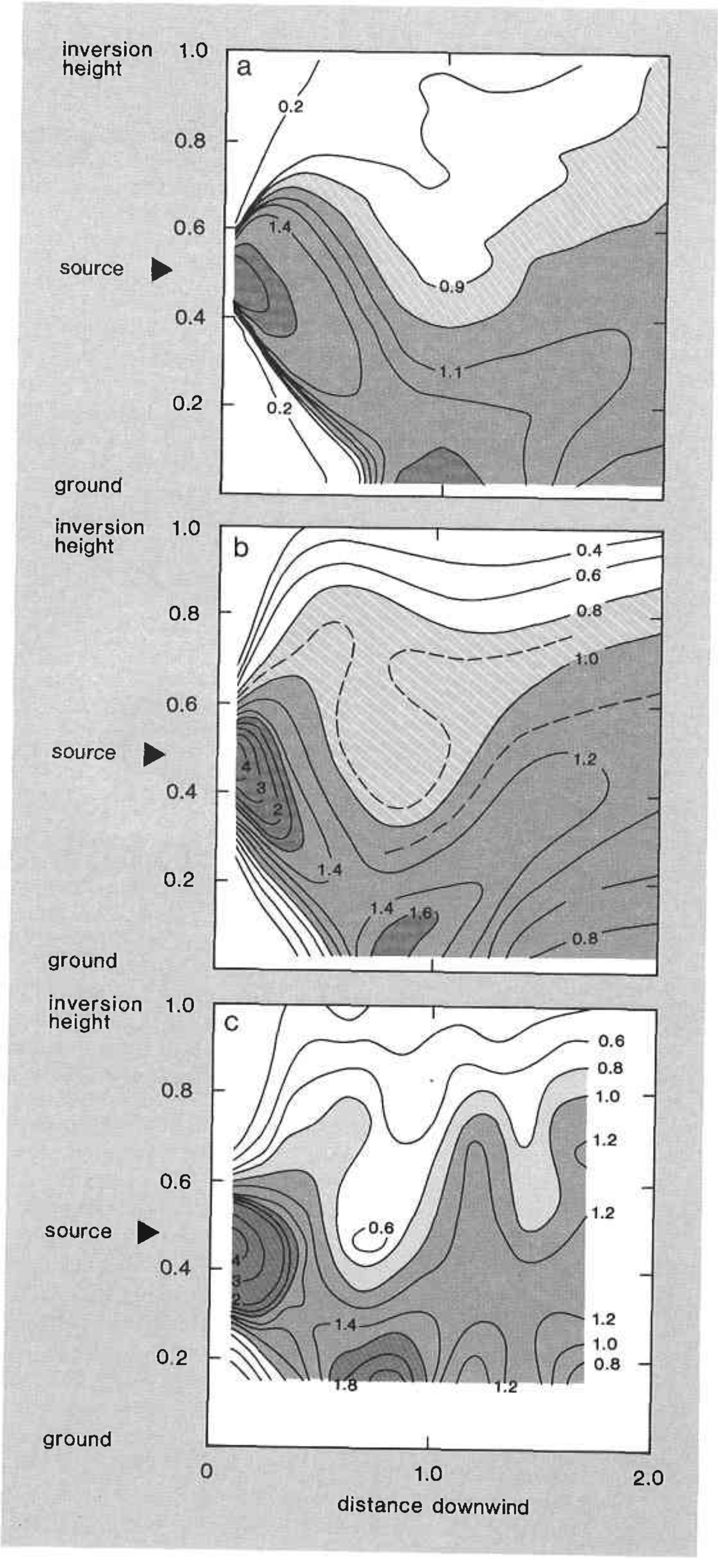
Numerical and laboratory simulations of airflow over a periodic series of ridges in thermally stable conditions have been undertaken in collaboration with Dr F. Kimura, a visiting scientist from the Meteorological Research Institute, Japan. This work was an extension of previous experiments carried out in the Division, this time using special numerical and laboratory techniques to approximate an infinitely deep fluid. A numerical method of selectively removing outwardly propagating internal gravity waves was employed, as was the laboratory technique of wave removal described above.

Results showed that partial flow stagnation, and hence, in practice, pollution build-up, in the periodic valleys in thermally stable conditions, occurred over a range of ambient winds, not as clearly defined as found in the earlier studies. Varying the incident wind direction showed the sensitivity of flow channelling along the valley axis to the Coriolis Force. Simulated surface cooling was shown to make the valley ventilation both more and less efficient depending on the circumstances.

Turbulent dispersion

The theoretical treatment of turbulent dispersion from a Lagrangian statistical viewpoint has continued. In this approach statistics of the concentration distribution of a contaminant in turbulent flow are calculated from the displacement statistics of small elements of fluid ("marked particles") as they move through the turbulence. The mean concentration and turbulent dispersion (i.e. the spread of a plume) in a fixed reference frame are both described by the statistics of independent marked particles, while the concentration variance and dispersion relative to the plume centre-line are described by the statistics of pairs of marked particles. Models used are based on the Langevin equation (well known from the theory of Brownian motion) and provide realistic prescriptions for the motion of independent marked particles and marked-particle pairs, incorporating both the effects of memory and spatial structure of the turbulence. Problems studied include:

- The effects of turbulence inhomogeneity (e.g. in the atmospheric boundary layer) on turbulent dispersion, focussing particularly on the break-down of the flux-gradient (or diffusion equation) approximation in strongly inhomogeneous flows (e.g. a strongly unstable boundary layer).
- The relationship between conditioned single-particle dispersion and relative dispersion with application to long-range dispersion in the atmosphere.
- The effect of molecular diffusion and viscosity on the evolution of concentration fluctuations in homogeneous turbulence.



Plume dispersion: a comparison of theory (a), laboratory experiment (b) and field measurements (c). Shown are concentration contours from a neutrally buoyant source in the middle of the mixed layer.

- The use of the 2-particle Lagrangian theory (including the extension to include the effects of molecular diffusion and viscosity) to model temperature fluctuation measurements in low Reynolds number homogeneous turbulence in a wind tunnel.
- Extension of the 2-particle theory to model concentration fluctuations in sheared homogeneous turbulence and in a neutral boundary layer.

Analysis of data previously collected in plume dispersion experiments in the atmospheric boundary layer is under way. Interest centres on higher order concentration statistics such as variance, skewness and kurtosis and the frequency distribution of concentration. These statistics are important in describing short-term "peak" values of concentration and also the uncertainty in concentration measurements or predictions. Both unconditional and conditional (zero values ignored) statistics have been calculated and their inter-relationship with the intermittency (proportion of non-zero concentrations) examined. The joint statistics of the concentration contributions from a pair of sources have also been examined with a view to allowing for the effects of correlation induced by the spatial structure of turbulence on the frequency of extreme concentrations from multiple sources.

An earlier theory of inversion penetration by buoyant plumes based on laboratory experiments has been tested on field data obtained downwind of the Gladstone power station in central Queensland. These data confirm that plumes can partially penetrate an inversion, with some material being mixed downward and some lost to higher levels. They support the earlier theory.

Wind tunnel and laboratory convection tank experiments to study turbulent dispersion are in formative stages.

Large-scale dynamics

Introduction

Atmospheric dynamics

Three-dimensional instability theory

Global transport processes and their representation in transport models

Diagnostics

Diagnostic studies of atmospheric circulation

Three-dimensional eddy propagation

The tropical circulation north of Australia

Climate diagnostics

Climate teleconnections

Paleoclimatic reconstruciton

Climate modelling

Drought research

Modelling of climatic variability

Middle atmospheric modelling

Tropical sea-air transfer

Atmospheric effects of nuclear war

Introduction

The general circulation of the Earth's atmosphere is an integral part of the complex set of factors which determine weather and especially climate. The primary objective of the large-scale dynamics program is to elucidate the mechanisms which determine this general atmospheric circulation. In studies of the general circulation it is found convenient to separate it into quasi-stationary (seasonal timescales or longer) or transient (shorter timescales) components. The quasi-stationary flow varies on longer timescales, and also interacts with the transient flow — as all these variations and interactions are not well understood, they need to be studied, especially as the longer timescale variations are largely responsible for the year-to-year variation in climate. Clearly, an improved understanding of all these processes is an essential prerequisite for the advancement of our knowledge of the dynamical basis of climate and its variability.

An important aspect of our approach to these problems is the broad range of techniques utilized. Theoretical approaches range from simple analytical studies of phenomena taken in isolation (e.g. via linear theory or simple mechanistic models), through more sophisticated approaches such Gas three-dimensional instability theory and the methods of statistical mechanics and quantum field theory, to fully nonlinear three-dimensional modelling studies. Another approach is to make maximum use of observational techniques: the development and application of novel diagnostic procedures to atmospheric circulation data will give greater insight into the essential processes maintaining the circulation. Finally, statistical analyses of past and current climatic data will help to identify patterns and relationships within the climate system.

Thus, there are the twin approaches of theory (atmospheric dynamics and general circulation modelling) and observation (diagnostics of atmospheric circulation) which form the core research program; in addition there may be specific issues to serve as a focus for applications of these core research programs — a current example is drought research, while in 1985/86 interhemispheric transport will be studied to enable an assessment of the atmospheric effects in the Southern Hemisphere of a Northern Hemisphere nuclear war.

Atmospheric dynamics

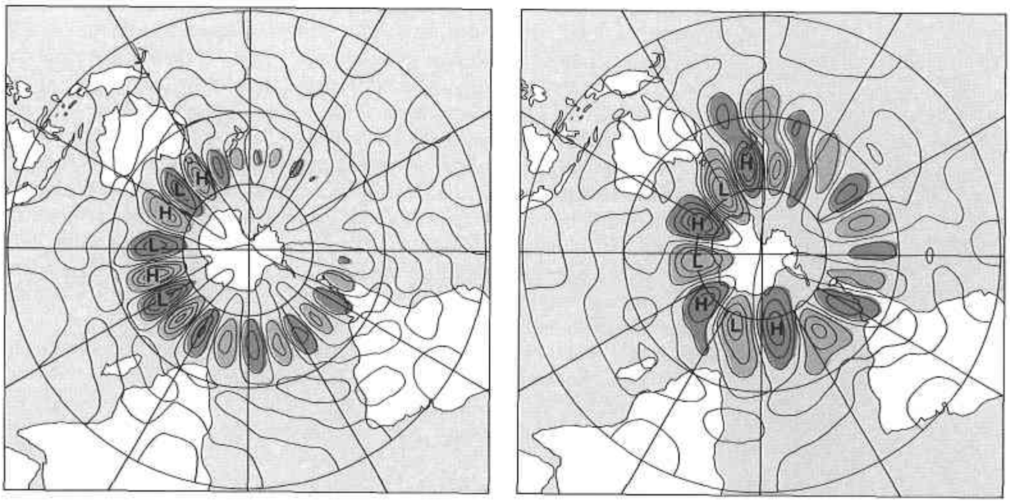
This subprogram comprises the study of the dynamics of the atmosphere by use of theory and numerical models based on these theories. The aim is to elucidate the physical basis of the dynamical processes that drive the atmosphere.

Three-dimensional instability theory

Large-scale dynamical processes of the extratropical troposphere are usually considered as processes in which the fluctuations have scales greater than about 250 km and periods larger than about 1 day. Within this range, there exists a wide variety of disturbances from relatively small-scale extratropical cyclones or lows, to anticyclones or highs, to blocking dipoles consisting of high-low pairs aligned in the north-south direction and to very large-scale teleconnection patterns which may be of hemispheric or even global extent. Here the word teleconnection refers to the fact that the climate in one part of the world may be related to the climate in a distant region, either positively or negatively, through these large-scale features of the circulation.

Blocks and other large scale systems may have a profound effect on the weather and climate, producing severe storms in some regions of the earth and droughts in others.

Recent work in the large scale dynamics group has focussed on a theory for explaining the dynamical mechanisms responsible for generating this spectrum of atmospheric disturbances. It turns out that a single theory, viz. three-dimensional instability theory, is able to generate disturbances of these different categories which are very similar to those observed. The roles of the different dynamical mechanisms which determine the structures, periods and growth rates of such disturbances can also be understood through the theory. So far the theory has been applied to explain the location of storm tracks in both Southern and Northern Hemispheres and the geographically preferred regions of blocks in both hemispheres. In the Northern Hemisphere instability patterns similar to most of the observed large scale teleconnection patterns have also been obtained for the winter situation and work is proceeding on studying these patterns for the Southern Hemisphere and for different seasons.



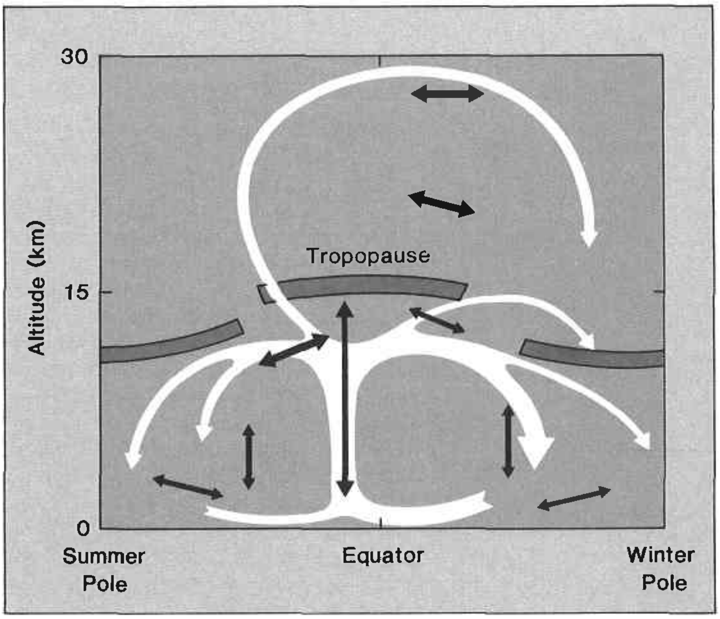
a b

Three-dimensional instability theory : calculated stream functions. a) The highs and lows of the instability disturbance corresponding to a typical Southern Hemisphere storm track. b) An instability disturbance showing the beginning of the formation of high-low dipoles and elongated highs and lows in the Tasman Sea corresponding to the beginning of a blocking system.

Global transport processes and their representation in transport models

Horizontal and vertical transport of atmospheric constituents around the globe by large-scale atmospheric motions has a profound influence on the distribution and global budgets of many constituents of climatic and environmental importance (including carbon dioxide and ozone). These processes must therefore be taken into account in assessments of the present (or predicted future) status of such constituents. Because of the prohibitive demands associated with the incorporation of chemical reactions into fully three-dimensional models, most such studies are based on simplified models, the most common and soundly-based of which is the two-dimensional (zonally-averaged) model, in which the effects of transport by the unresolved eddy motions must be parameterized. Applications of these modelling studies are described in the report on atmospheric constituents.

Studies of the kinematics of large-scale atmospheric transport laid down in principle a procedure for parameterizing the effects of eddies as the sum of advective and diffusive processes. However, this procedure could not be implemented using atmospheric circulation data from routine global analyses of the circulation because the required data (which include vertical motion statistics) are not available at reasonable accuracy. Instead, numerical model data were used and, in collaboration with Dr J.D. Mahlman (Geophysical Fluid Dynamics Laboratory, Princeton University, USA) the transport properties of the GFDL general circulation/tracer model were derived in a form suitable for application in two-dimensional models. The dynamical processes responsible for the bulk of the transport were identified: strong vertical transport in the tropical troposphere and strong quasihorizontal transport in the mid-latitude lower troposphere (associated with synoptic baroclinic disturbances) and in the "surf zone" of the tropical troposphere and subtropical winter statosphere, where planetary-scale waves break in the weak prevailing winds. As a check on the basic reliability of this two-dimensional approach, these results were used to construct a two-dimensional model which, on the basis of a number of comparison experiments, was found to reproduce reasonably well the behaviour of the parent three-dimensional model. This parameterization is now used in models of the global carbon cycle (Atomospheric Constituents Report).



Transport processes in the atmosphere are responsible for the global distribution of atmospheric trace chemicals released into the atmosphere. Shown is a schematic representation of these processes, as determined from a general circulation model. Open arrows represent advection by the mean circulation; closed arrows represent dispersion by eddies.

Diagnostics

An important approach to improved understanding of the dynamical processes operating in the atmosphere, especially on the larger scales, is through detailed analysis of the atmospheric flow. As the amount of information available from observations may vary, and can be hard to interpret, new diagnostic procedures need to be developed to allow researchers to gain new insights in the workings of the atmosphere.

Diagnostic studies of atmospheric circulation

Three-dimensional eddy propagation

Application of so-called "Eliassen-Palm" diagnostics (a process for assessing the joint impact of heat and momentum transport by eddy motions) to atmospheric circulation data has proved a very powerful approach to the analysis of wave propagation and transport on zonally-uniform flows. However, the versatility of the technique has been restricted by the need to take zonal averages of the eddy statistics, thus suppressing information on zonal variations. Efforts have been directed at developing parallel procedures for the three-dimensional analysis of observed flows and techniques thus developed have been used to examine the propagation of stationary planetary waves (one notable result of which was the apparent absence, contrary to expectation, of tropically-forced wave components in the stationary wave field) and travelling synoptic eddies. Work is continuing to develop a theory of the interaction of these transient eddies with the time-averaged, climatological, flow. This will allow an improved assessment of the influence of travelling eddies on the three-dimensional general circulation and its variability.

The tropical circulation north of Australia

A study has begun of the climatology of the tropical atmosphere in the Indonesian region, using the routine tropical regional analyses of the Bureau of Meteorology. Amongst other things, the circulation thus defined is being compared with that revealed by analyses of the European Centre for Medium Range Weather Forecasts; the latter show unusual features of vertical structure which are not present in the Australian analyses. This is thought to arise from deficiences in the initialization procedure employed by ECMRWF.

Climate diagnostics

Climatic teleconnections

A study of the stability or otherwise of a number of claimed climatic teleconnections, or relationships between climatic fluctuations at widely separated places (El Nino), revealed a number of cases of apparent breakdown in such relationships. This raises potential problems in the application of such teleconnections, where time-lags are involved, to seasonal forecasting. It appears that such relationships often hold up pretty well for several decades, but may then break down or even reverse for intervals of a decade or more.

Reasons for such intermittent relationships are being sought. They could simply be manifestations of the statistical unreliability of relationships which do not account for all the variance in the data. However such partial relationships usually mean that other factors are also important, and it follows that if such extraneous factors can also be identified it may be possible to account more fully for the observed variations. One possibility is that the teleconnections are conditional on certain key boundary conditions remaining constant, when in fact they vary as the overall climate slowly fluctuates. This possibility is to be further explored.

The 1982/83 drought in Eastern Australia, which was one of the worst on record, is thought to have been due to the El Nino phenomenon. El Nino refers to a major ocean/atmosphere disturbance over the Pacific which occurs once every 3–5 years. Improved understanding of the cause of El Nino is expected to lead to improved forecasting of major droughts in Australia.

Palaeoclimatic reconstruction

Joint work with scientists in the UK has led to a conceptual model of the climatic changes during the last glacial/interglacial transition based on the influence of changed boundaries of high latitude snow and ice on the north-south temperature gradients in the Northern and Southern Hemispheres. Resulting estimates of changes in the location of major circulation features such as the equatorial trough and the subtropical anticyclones, and consequent changes in the hydrological regime were verified against palaeohydrological evidence from Africa, western Eurasia and Australasia for the periods around 18 000, 9000 and 6000 years before present. This tends to confirm our understanding of the key role played by these features in climatic change.

Climate modelling

An important application for the general circulation models developed by atmospheric scientists is their use in studies of climate variability. In order to ensure a 'physical reality' of the models, information on physical processes occurring in the atmosphere and between the atmosphere and the Earth's surface and oceans needs to be incorporated.

Drought research

Modelling of climatic variability

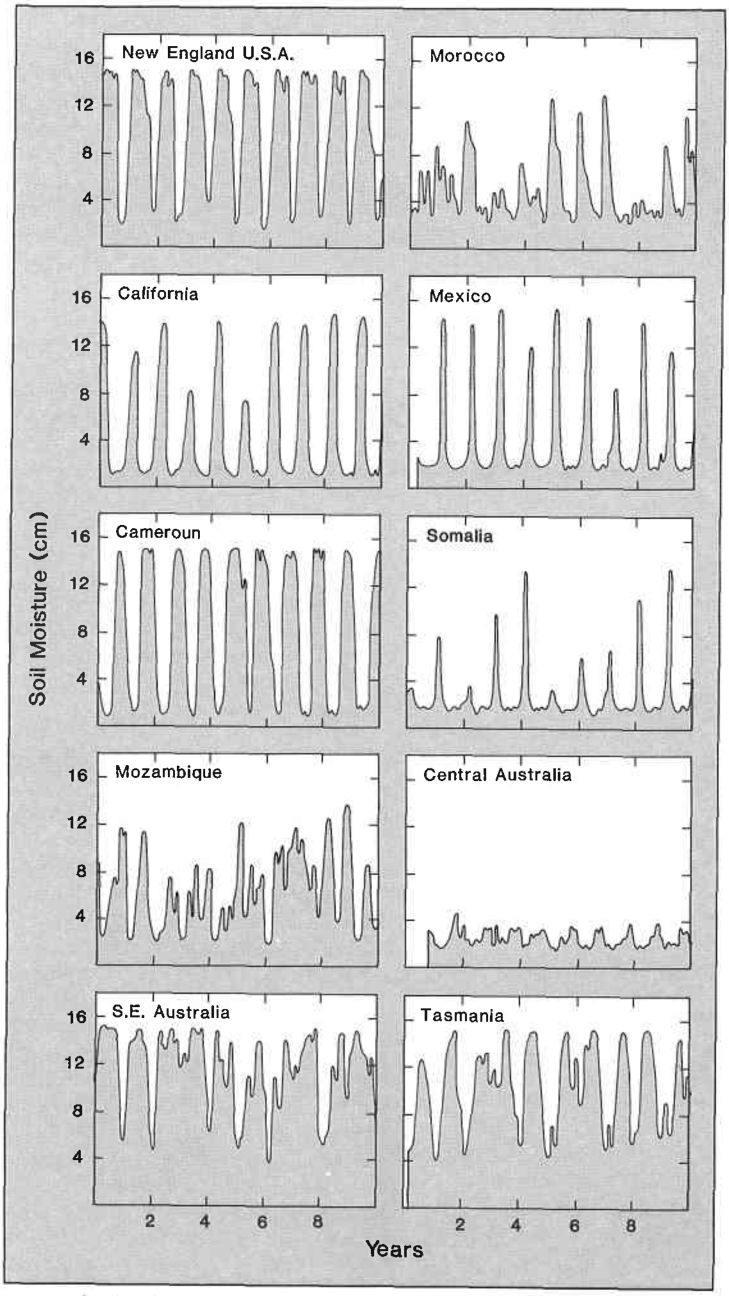
The two-level general circulation model from the Australian Numerical Meteorology Research Centre has been transferred to the CYBER 205 computer for use in research on the large scale characteristics of drought. Initial experiments will involve specifying climatological sea surface temperatures in multi-annual integrations, in continuation of the research initiated at ANMRC. Immediate priorities include developing the model so that it can be coupled with an oceanic model in order to investigate the impact of naturally occurring sea surface temperature anomalies on drought.

Currently final analyses of the surface hydrology characteristics of a 10 year simulation with the model are being completed. Many diverse forms of interannual variability have been identified in the results, and these provide considerable encouragement for the viability of the project. Some typical examples are shown in the figure below. The soil moisture contents shown in the diagram are very highly correlated with local precipitation so that the figure essentially records smoothed precipitation rates. Of particular interest is the apparent occurrence of drought at certain locations, see Morocco, California and Somalia for example. Since there is no forcing mechanism, such as sea surface temperature anomalies, in the model to create these droughts they have been termed "naturally occurring" and attributed to nonlinear processes operating within the climatic system. A more detailed analysis suggests that they are not necessarily associated with a lack of available atmospheric water vapour for precipitation, but rather to the failure of the convective mechanism to operate for the given environmental conditions in the model during the drought years.

A one-dimensional radiative convective model has been coupled with various schemes for simulating soil hydrology in climate models. This has highlighted the considerable deficiencies of the scheme which is in almost universal use, and indicated a scheme which has noticeable advantages for climatic simulation.

Middle atmosphere modelling

Development of a global model of the middle atmosphere extending from 0–100 km is continuing. A recent production run included the diurnal variation of solar heating and the incorporation of Lindzen's gravity wave breaking drag parameterization for the mesosphere. The latter produced a substantial reduction in the strength of the winter



A 10 year computer simulation of soil moisture variations, using a general circulation model of the atmosphere. Results are shown for a number of representative geographical locations, and illustrate the marked interannual variability.

mesospheric jet resulting in much improved agreement with observation, and saw the replacement of the previous multi-celled mean meridional circulation in the mesosphere by a direct pole-to-pole circulation. Above 70 km the synoptic patterns in the model were dominated by the tides, again resulting in an improved agreement with isolated station data. This is the first time the tides in the middle atmosphere have been modelled synoptically; no comparable observations are available.

Currently the model is being further developed by allowing for a stochastic variation of the phase velocity of the gravity waves in the drag parameterization. The stratospheric gravity wave drag parameterization scheme of the British Meteorological Office is also being evaluated in the model with a view to overcoming the cold bias of the polar winter stratosphere. Finally the Newtonian radiation scheme used in the model from 70–100 km is now based on a relaxation to radiative equilibrium temperatures.

Tropical sea-air transfer

The input of heat and evaporative latent heat from the sea surface into the atmosphere, especially in the lower latitudes, is of great significance, since it provides the energy to drive the world's major atmospheric systems which produce the climate and its variations.

The bulk transfer relationship has become established as the conventional means of evaluating these fluxes from the surface, whether from actual shipboard measurements or in theoretical or computer modelling. But this relationship becomes unreliable in light winds and breaks down completely in winds lighter than about 2ms-1, when the process of free convection becomes dominant. Since light winds are common over the tropical seas and over a large part of the Pacific — regions where very significant inputs of heat and water vapour occur — this poses a serious difficulty.

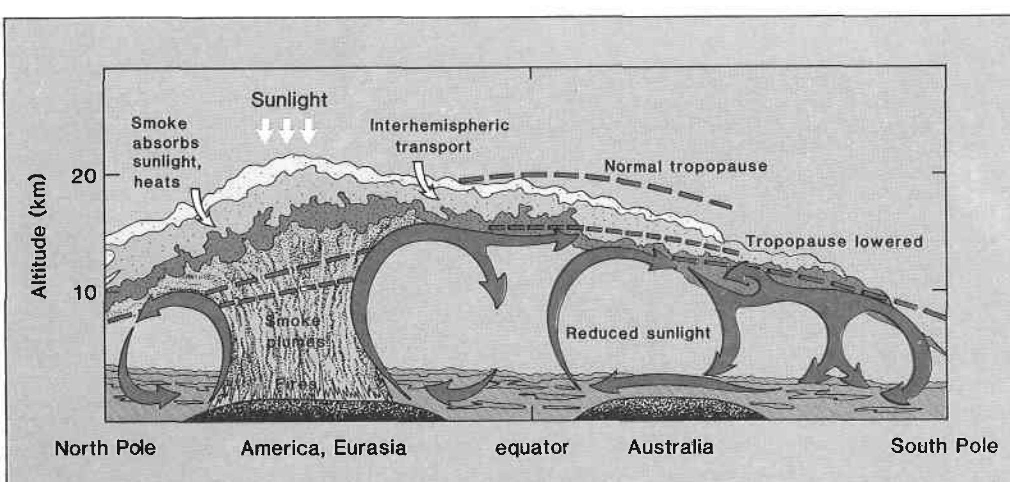
The only attempt to overcome this problem has been in the development a few years ago of a formulation based on coupling the free convection regime to a thin boundary layer of molecular transfer at the surface. This, however, involves uncertainties which could be overcome only by the development of a comprehensive theory of the complete free-convection process. Recently, it has been found possible to develop the framework of such a theory. At the present stage it has been confirmed that the results have the correct form at the two extremes, very near to and very far from the surface. Work on the much more elaborate details over the whole range is proceeding.

It is expected that completion of the theory in the near future will set on a sound basis the extension of the bulk relationship to remain valid for wind speeds down to zero.

Atmospheric effects of nuclear war

Research by a number of scientists around the world has recently brought to light that in addition to the 'well-known' harmful effects of a nuclear war such as the destruction from the initial blasts, the possible damage to the ozone layer, the damage from radiation and radioactive fallout, there is also the risk of the Earth's climate being affected. This theory of the 'nuclear winter' is based on the postulated cooling effect of nuclear war-generated smoke, dust and other debris,

Fires generated by a major nuclear war in the Northern Hemisphere would project large quantities of smoke into the lower 8–10 km of the atmosphere (the troposphere), which is bounded by the tropopause. The smoke would absorb incoming solar radiation, which would cause it to rise into the stratosphere, where, at a height of around 15–20 km, it would move south across the Equator.



which, when lifted into the stratosphere during a war in the Northern Hemisphere, would intercept the incoming solar radiation while remaining relatively transparent to outgoing heat radiation.

Scientists in the Division's Atmospheric Constituents and Small-scale Dynamics groups have already contributed to research on plume rise from massive forest fires and have worked on quantifying smoke inputs into the atmosphere.

Much of the attention of scientists working on the atmospheric effects of nuclear war has centred on the consequences for the Northern Hemisphere. The Division has contributed to a number of reviews of the subject, placing particular emphasis on the possible effects on the Southern Hemisphere. These reviews highlight the need for further research addressed especially at interhemispheric transport of the nuclear war-generated smoke, and its possible effect on climate in our part of the world. Plans to undertake a research effort in this area will commence in 1985/86, under a grant from the Australian Department of Foreign Affairs for the International Year of Peace.

Activities

Technology transfer

As the Division of Atmospheric Research is engaged in research into *weather, climate* and *air pollution*, its main task in **'technology transfer'** is to ensure that results of its research on the environment is utilized by agencies charged with the provision of monitoring, forecasting and warning services. For this reason DAR maintains contact with the Australian Bureau of Meteorology; power generating bodies such as the State Electricity Commission of Victoria and the Queensland Electricity Generating Board; environment protection bodies such as the Environment Protection Agency of Victoria and the State Pollution Control Commission of New South Wales; and water authorities and bushfire fighting services such as the Country Fire Authority of Victoria. On the international scene extensive collaboration and exchange of information takes place with atmospheric research agencies such as the National Center for Atmospheric Research (USA), the Geophysical Fluid Dynamics Laboratory, Princeton (USA) and the European Centre for Medium Range Weather Forecasting (UK).

Typical research projects which highlight the collaboration and 'technology transfer' referred to above, and described elsewhere in this report, are:

- The Cold Fronts Research Programme
- Studies of Melbourne's air quality problems
- Development of numerical forecasting models (ANMRC)
- Studies of climate variability
- The Latrobe Valley Airshed Study
- Calibration of high-resolution C-band weather radar

There is, perhaps surprisingly, a second form of technology transfer operating at the Division. This concerns the transfer to manufacturing industry of new instrumentation or technology which was developed at the Division in support of its research programs. Whereas the first and foremost objective is to devise new instruments or methods for studying aspects of *weather, climate* and *air pollution*, the potential for commercialisation of our inventions has been recognised, and is receiving a considerable amount of attention.

Over the last few years, several technology transfer ventures have taken place:

- **UHF radiosonde receiver**
  Radiosonde receivers now in production at PCM Electronics Pty. Ltd., Melbourne, for the Bureau of Meteorology, are based on technology developed at the Division in support of its atmospheric research program.
- **TV masthead amplifier**
  A very low-noise, wide band-width amplifier developed for meteorological balloon telemetry applications has been found to offer significant performance advantages over existing amplifiers, when used in TV masthead applications at fringe-signal sites. The amplifier is being manufactured by Onsite Aerial Services, Melbourne.
- **Measuring knitting yarn**
  Opto-electronic counters used for sensing the rotation of anemometers have been adapted for measuring the yarn length used by circular knitting machines. The instrument allows for the accurate sizing and repeatability of production in, for example, sock manufacture. The low-cost yarn sensor may be readily attached to standard knitting machines. The device is

being used by Humphrey Law & Co. Pty. Ltd., of Heathmont, Vic.

- **Hot wire liquid water detector**
  A liquid water detector for use in field experiments on the microphysical properties of clouds has been developed and built. This detector is now being produced and marketed by an American company, Particle Measuring Systems Inc.
- **Automatic rain gauge**
  A low-cost, reliable automatic rain gauge has been developed for rainfall recording. The instrument is capable of recording for a 6 month period without operator access, and is ideal for use in remote locations. The instruments are used extensively during field experiments and more than a hundred copies have been built at about $600 each. Copies of the instrument are also being made and used by the Spanish Meteorological Service.
- **Commercialization of CSIDA**
  The satellite data acquisition and analysis facility developed at DAR will be marketed in the form of meteorological satellite data receiving stations, together with image processing workstations.

(i) ***Satellite tracking antenna and data acquisition system***
A Melbourne Company, PCM Electronics Pty. Ltd., has signed an agreement with CSIRO to manufacture and market this facility. This includes a satellite tracking antenna, the tracking controller, the receiving system and the data acquisition and control system.

(ii) ***New image processing workstation***
Jointly with Dindima Pty. Ltd., the Division is developing an image analysis workstation to be used for processing of satellite imagery and related image processing tasks. The workstation will be produced and marketed by Dindima, and is designed to be available at low-cost, using state of the art software and hardware technology.

Support services

Like all research establishments, the Division of Atmospheric Research has a substantial number of staff engaged in activities which are essential to support the research effort. Activities range from Administration to allow a smooth running of the financial and personnel management of the Division, to the essential services from the Facilities Group to maintain existing and construct new research instruments. To allow an appreciation of the nature of such support services, and to highlight the fact that they are indispensable to the outcome and dissemination of the Division's product (research results), a brief summary is given below.

Facilities

The facilities group provides engineering and computing support to the Division's research programs. It designs and develops specialised scientific instrumentation, provides computing services via extensive local facilities and CSIRONET, participates in the transfer of technology to industry, and manages and maintains buildings, facilities and services. Some major activities are outlined below:

Engineering

During the reported period, particular emphasis was placed on the introduction of new technology and the support of several major field programs. New technology included the development and commissioning of signal reception and image processing facilities for geostationery and polar orbiting meteorological satellites, the extensive implementation of microprocessor based systems into divisional instrumentation and the introduction of computer aided design and manufacturing capabilities.

Field programs, including the extensive engineering support of research goals by instrumentation and direct participation, were undertaken. Programs covered cloud radiation and atmospheric chemistry experiments aboard the CSIRO F27 research aircraft and R.V. Sprightly; the most extensive atmospheric research field program ever conducted in Australia for studies of meteorological cold fronts (the Cold Fronts Research Program); continued instrumentation support for various programs at the Baseline Air Pollution Station, Cape Grim, and research programs in the Latrobe Valley, Mildura, Coffs Harbour and Griffiths. A summary of the field experiments conducted in the period 1983-85 is given in the Table below.

The design of a major building extension was completed in liaison with the Department of Housing and Construction and CSIRO Buildings Section, to accommodate staff transferred to Aspendale from Sydney and Melbourne. Due to financial constraints this building is yet to be constructed and significant temporary accommodation has been developed as an interim measure.

Field experiments

The Division has continued to carry out an important part of its research by means of field observations. As usual, extensive technical support has been provided to these various field experiments over the past two years.

Experiment	Description
Cape Grim Baseline Station	This permanent field station is used extensively for sampling of atmospheric trace gases and aerosols. Other experiments concern rainwater chemistry, and radiation studies.
Coffs Harbour Experiments September, 1983 May, 1984	Cloud studies using the CSIRO F-27 Research Aircraft. Development of the Spectrally Scanning Radiometer (SPERAD).
Cold Fronts Research Programme November, 1983 November, 1984	Large field experiments centered on Mt Gambier, observing cold fronts as they pass over South Australia and western Victoria. Use of ground-based observational network, CSIRO F-27 aircraft, with support of the Bureau, RAN, RAAF, Army and several Universities.
Latrobe Valley Plume Studies June, 1984 March, 1985	Plume tracking studies in the Latrobe Valley, using aircraft and ground-based observations. During the March 1985 experiment plume rise was also studied with ruby lidar.
Rainfall field studies July–August, 1984	Raingauge network, C-band radar and F-27 field studies near Richmond, NSW, to examine effects of orography on rainfall and to study rainfall in the Grose Valley.

Mildura Aerosol Experiment October, 1984	Aerosol studies using the CSIRO F-27 aircraft and the ground-based ruby lidar.
Mildura "Aspire" Experiment June–July, 1985	Ground-tracking of mixed phase cloud, using the CSIRO F-27 aircraft SPERAD, the F-27 microphysics package, and the ground-based lidar unit.
Griffith and Tatura Field Studies November, 1984 and February, 1985 respectively	Soil exhalation studies dealing with the production of nitrogen oxides in soils and crops.
"Sprightly" Cruises July–December, 1984	A number of field studies to collect ground truth data for satellite sea surface temperature measurements.

Computing

The Division has developed, over many years, one of the most extensive CSIRO computing networks outside of CSIRONET. The network supports numerous real-time experiments and data analysis facilities including the analysis of field data, and computing associated with the more straightforward numerical modelling of atmospheric processes.

A major extension to the Computing Laboratory building has allowed for the improved organisation of computing equipment and for the installation of additional computing facilities associated with satellite image processing and enhanced requirements in other areas.

The Division makes extensive use of CSIRONET computing facilities for weather and climate modelling and associated research. The transfer of complex software to the new CYBER 205 super computer is in progress.

Scientific services

This name conveniently describes the assistance provided to support the Divisional research effort and to maintain the Division's contact with the scientific community and the world at large. As part of these services the Division maintains its own library, which forms part of the overall CSIRO library network. The 1983-85 period has seen a lot of activity, brought on in part by the need to cater for the newly amalgamated and expanded Division, and in part by the need to update the library in line with developments in other parts of CSIRO.

The new Division's Library is based on the Division of Atmospheric Physics collection, but in addition, large scale transfer of material from the Cloud Physics Laboratory in Sydney and replacement of part of the collection transferred to the Bureau of Meteorology from the ANMRC have resulted in a substantial increase of the library stocks. Staff and space constraints mean that this process will probably not be completed for some years. As the Atmospheric Physics Library had made minimal use of on-line information services and the automated cataloguing systems of the CSIRO Library Network, a major programme of recataloguing into machine readable form was begun in 1983. This in anticipation of an integrated on-line automated library system (CLINES) becoming available throughout CSIRO in 1986. In addition, an alphabetical subject catalogue was introduced to enable subject access to the collection which was lost when the original classified subject catalogue was abandoned and discarded some years ago. Further developments in the Library services are being severely hampered by the shortage of storage, reading and working space in the existing Library. It is hoped that a building to house the enlarged Library will be commenced in the near future.

A second aspect of scientific services is the photography/graphics area. Support is provided not only for the preparation of artwork and photographs for scientific publications, but also to support other activities such as posters and slides for presentation at conferences and special display for other purposes such as VIP visits. Professional photographic support to scientific photography is provided, and in addition, video clips can now be produced to describe major developments and research activities.

Examples of the support provided for promotional activities are a glossy brochure and an 18-minute video clip describing the Division's satellite data acquisition and image processing facility, known as CSIDA. Both were used during an official launch of the commercial version of CSIDA at ANZAAS in August 1985.

The third area which belongs to the scientific services group covers a range of duties related to public relations and scientific support for the Chief. The public relations part includes internal and external Newsletters reporting on activities in the Division and recent publications; the provision of information about the work of the Division to the general public; liaising with the press and electronic media and the coordination of occasional visits to the Division by VIP's, schools, teachers and other members of the public. The scientific support of the Chief's Office consists of assistance with the preparation of submissions, reports, and responses to CSIRO policy matters. This also includes the secretarial support for the Divisional Advisory Committee, which had its Inaugural Meeting in February, 1984, and which meets twice a year.

One additional service which deserves attention is the support the Division provides in making staff available to serve on, and be of assistance to, Conference Organising Committees. A list of Conferences for which the Division provided the secretariat is given in the Table below.

Conferences and Workshops supported by the Division of Atmospheric Research July '83 — July '85

Date	Meeting
February 6–10, 1984	"International Conference on Mesoscale Meteorology" Held at Melbourne University. 170 participants
February 13–16, 1984	"1st Australasian Conference on the Physics of Remote Sensing of Atmosphere and Ocean" Held at Ormond College, Melbourne University. 140 participants
April 17, 1984	"Lead Scientist Symposium — Cape Grim Baseline Station" Held at the CSIRO Division of Atmospheric Research 20 participants
June 26, 1984	"Mesoscale Models and their Application to General Meteorological Problems"

	Held at the CSIRO Division of Atmospheric Research 40 participants
November 7–9, 1984	"The Scientific Application of Baseline Observations of Atmospheric Composition" Held at the CSIRO Division of Atmospheric Research 65 participants
February 27–28, 1985	"CSIRO Space Science Seminar" Held at the CSIRO Division of Atmospheric Research 70 participants.
March 28–29, 1985	"Australia and New Zealand Environmental Effects of a Nuclear War — Workshop" Held at the Royal Society of Victoria. 60 participants

Administration

The administrative group provides Personnel, Budgeting, Purchasing, Word Processing, Reception, Travel and Transport services to the Division.

With the amalgamation of the Division of Atmospheric Physics, ANMRC and the Division of Cloud Physics after the Review of Atmospheric Sciences in CSIRO, the administration was required to assume responsibility for two remote sites in addition to its responsibilities in Cape Grim and Hobart (for CGBAPS). This entailed extra travel and rearrangement of administrative systems to cope with the increased load and the difficulties of remoteness from the Headquarters at Aspendale.

Generally most arrangements went smoothly, although with the planned new building being postponed, increasing pressures were brought to bear on funding and support services due to the need to provide temporary accommodation for new staff on the Aspendale site. Upgraded word processing, PABX, copying and computing facilities were required and these were put to the test as many of the DCP and ANMRC staff decided to transfer elsewhere and a major recruitment campaign began in early 1985 to replace them in Aspendale.

A number of staff in the administrative section were promoted during this period in recognition of the increased scope of their duties and a major reorganisation took place to facilitate the increase in workload and the change over of the organisation to accrual accounting and a planned on-line financial management system.

Visitors

An important aspect of the Division's well-being is the contact with fellow scientists in other research institutions, both in Australia and overseas. The exchange of ideas, catered for in part by publication of research results in scientific journals and technical reports, is promoted and fostered by visits of the Division's scientists to other establishments (see the Personnel, Affiliations sections and the list of Conference Presentations) and by the Division's encouragement of scientists from elsewhere to visit DAR.

In recent years a special category of visitors has emerged which, although not strictly scientific, is also perceived as important to the well-being of the Division. Listed as VIP visits, the reader will find a diverse list of prominent figures who, by being familiar with the Division's research program and achievements, may contribute to the Division's aim of fostering community awareness of DAR's role in research on weather, climate and air pollution.

For visitors to DAR, distinction has been made between short visits of one or two days, usually including a seminar presentation, and visiting scientists, who have stayed at the Division over a prolonged period, in general with financial support from CSIRO.

VIP visits

7 November 1983
Mr Bob Chynoweth, MHR, Member for Flinders

24 February 1984
Inaugural Meeting of the **Divisional Advisory Committee**

4 April 1984
Brigadier Ian Gilmore, Director, Australian Counter Disaster College, Mt. Macedon, and staff.

2 May 1984
Dr Paul Wild, Chairman of CSIRO
Dr Geoff Taylor, Member of CSIRO Executive.

19 September 1984
Second Meeting of the **Divisional Advisory Committee**

25 October 1984
Mr Michael Schildberger, ABC Radio 3LO.

8 November 1984
Hon. Barrie Jones, MHR, Minister for Science and Technology.

14 November 1984
Mr Ian Cathie, Victorian Minister for Housing, Industry and Commerce
Mr David Charles, MHR, Member for Isaacs.

15 January 1985
Professor John Swan, Australian Marine Science and Technology Advisory Council (AMSTAC)

26 February 1985
Mr David Ellyard, Producer of Quantum, ABC-TV.

26 March 1985
Mr Michael Barnard, The Age.

27 March 1985
Delegation of the People's Republic of China, led by **Mr. Jou Zinmeng**, Head of the State Meteorological Administration, China.

22 April 1985
Mr Roy Green, Deputy Secretary, Department of Science.

30 April 1985
Third Meeting of the **Divisional Advisory Committee**.

21 May 1985
Professor Brian Anderson, Head of Systems Engineering, R.S.Phys.S., Australian National University.

23 May 1985
Dr Geoff Taylor, Member of the CSIRO Executive.
Mr Graham Spurling, Managing Director, Mitsubishi Motors, Australia. Ltd. Part-time member of the CSIRO Executive.

24 May 1985
Dr Greg Teggart, Secretary, Department of Science.
Dr John Zillman, Director of Meteorology.

6 June 1985
Dr John Maddox, Editor of **Nature**.

12 June 1985
Mr Tony Lamb, MHR, Member for Streeton.

Visiting scientists

Dr H. Isaka	Laboratoire Associé de Meteorologie Physique, Clermond-Ferrand, France.	7 Jul – 9 Sep '83
Prof. B.P. Leonard	City University New York, USA.	7 Nov – 19 Dec '83 and 2 Apr – 14 Jun '84
Prof. G.E. Hunt	Imperial College, London, UK.	1 Feb – 1 Mar '84
Dr M.L. Thompson	CSIRO Division of Maths & Stats. (two-days/week)	Feb '84 – Jan '85
Dr M. Huffaker	NOAA, Boulder, USA.	9 Feb – 9 Feb '84
Dr A.G.M. Driedonks	K.N.M.I. (Roy. Neth. Met. Inst.) De Bilt, The Netherlands.	13 Feb – 24 Feb '84
Dr K.P. Hoinka	Institut für Physik der Atmosphäre Oberpfaffenhausen West Germany.	27 Feb – 9 Mar '84
Mr I. Simpson	NZ Met. Service, Wellington, New Zealand.	14 May – 27 Jul '84
Dr R.A. Pielke	Colorado State University, Fort Collins.	14 Jun – 6 Jul '84
Dr F. Kimura	MRI, Tsukuba, Japan.	18 Jun – 14 Dec '84
Dr D. Booth	Footscray Inst. of Technology, Melbourne. (one-day/week)	Sept '84 – Dec '84
Dr T. Takashima	MRI, Tsukuba, Japan.	1 Oct – 2 Dec '84
Prof. W.J. Megaw	York University, Downsview, Canada.	18 Oct '84 – 1 Apr '85
Dr P.P. Tans	Lawrence Berkely Laboratory, Berkeley, USA.	17 Nov – 28 Dec '84
Prof. J. London	University of Colorado Boulder, USA.	2 March – 30 Apr '85
Dr S. Asano	MRI, Tsukuba, Japan.	9 Apr – 4 Jul '85
Dr K. Landman	CSIRO Division of Maths & Stats (One-day/week)	Apr '85 – Jul '85
Dr A. Miller	CSIRO Division of Maths & Stats (One-day/week)	Apr '85 – Jul '85
Prof. J. Weinman	University of Wisconsin Madison, USA.	28 May – 11 Jul '85

Short visits

Mr J.R. Stranghan,	S. California, Eddisum Co., Rosevend, USA.	1 July '83
Dr B.B. Hicks,	Atm. Res. Labs. Oak Ridge, USA.	Aug '83
Dr W. Hsieh,	University of N.S.W., Sydney.	29 Sep '83
Dr H. Tominaga,	Nagoya University, Japan.	19–20 Oct '83

Dr N. Tominaga,	Ochanomizu University, Japan.	19–20 Oct '83
Dr P.R. Bell,	Inst. for En. Analysis, Oak Ridge, USA.	Aug '83
Dr S. Suyehiro,	Japanese Meteorological Agency, Japan	13 Dec '83
Dr B. Golding,	UK Met. Office	2 Feb '84
Dr D. Wratt,	NZ Met. Service, Wellington, New Zealand	20 Feb '84
Dr P. Broadbridge,	CSIRO Division of Environmental Mechanics, Canberra	30 Mar '84
Dr P. Linden,	University of Cambridge, U.K.	12–13 Apr '84
Dr A. Winer,	University of California, U.S.A.	11 May '84
Dr A.J. Prata,	W.A.I.T., Perth	25–29 Jun '84
Dr S. Bradley,	University of Auckland, New Zealand	4–6 July '84
Dr R. Griffith,	RSES, Australian National University, Canberra	12 July '84
Prof. A. Maxworthy,	University of Southern California,	12 July '84
Dr J. Simpson,	Goddard Space Centre, NASA	17 Oct '84
Dr J. Landsberg	CSIRO Division of Forest Research Canberra	5 Nov '84
Dr R. Rasmussen,	Oregon Graduate Centre,	Nov '84
Dr R. Cowood,	Victorian Crops Research Institute Horsham	13 Nov '84
Dr P. Isdale,	AIMS, Townsville	28 Nov '84
Dr E. Zipser,	NCAR, Boulder, U.S.A.	30 Nov '84
Dr M. Venning,	Scientific Counsellor, Australian Embassy, Tokyo	7 Dec '84
Dr D. Keyser,	NASA	19 Dec '84
Prof. A. Gagin,	Hebrew University of Jerusalem Israel	Dec '84
Dr D. Griffith,	Max Planck Inst., Mainz, West Germany	29/30 Jan '85
Dr M. Kanamitsu,	Japan Meteorological Agency, Japan	31 Jan '85
Prof. D. Lilly,	University of Oklahoma, U.S.A.	31 Jan '85
Dr P. Das,	Texas A & M University, U.S.A.	1 Feb '85
Prof. K. Emanual,	M.I.T., U.S.A.	1 Feb '85
Mr Y. Mano,	Japan Meteorological Agency, Japan	21 Feb '85
Dr D. Parkhurst,	Indiana University, Bloomington, U.S.A.	13 Mar '85
Dr A.B. Mullen,	NZ Met. Service, New Zealand	26 Mar '85
Dr D. McKenny,	University of Windsor, Canada	30 Apr '85
Prof. M. Williams,	Monash University, Melbourne	10 May '85
Dr P. May,	University of Adelaide	20 May '85

In addition, many of the scientists attending scientific meetings in the Melbourne area (see report on Conferences coordinated by DAR, in the Services Section) have taken the opportunity to visit the Division.

Personnel

As in the past, Divisional professional staff have been actively involved in collaboration and the exchange of ideas with scientific institutions and colleagues both in Australia and overseas. In addition, they have served on national and international committees. To stimulate research and to strengthen international contacts, scientists have travelled overseas to visit scientific establishments and attend conferences. Although the Division has a budget for overseas travel it is important to note that many such visits have been supported financially by the host institution.

New staff, affiliations and overseas visits

AYERS, Greg. Greg joined the Division from the Cloud Physics Laboratory in Sydney, and is a member of the BAPS Working Group. In 1983 and 1985, in collaboration with Ian Galbally, Greg lectured at Melbourne University to graduate students.

BAINES, Peter. In August, 1983, Peter attended the IAMAP symposium in Hamburg. From August to November 1984 he was a visiting Fellow at the Joint Institute for the Study of the Atmosphere and Ocean, University of Washington. Peter also visited other institutions in the USA and UK during December 1984 and January 1985.

BARTON, Ian. Dr. Barton attended the New Zealand Meteorological Service Conference in New Zealand in October 1983 and spent six weeks in Europe and the USA in August and September 1984 visiting a number of establishments for discussion on satellite measurements of sea and cloud surface temperatures. Ian also visited Europe and Canada for three weeks in April 1985 as a member of a team investigating the possible installation of an X-band satellite receiving station in Australia. In May 1985, he attended an international COSPAR Workshop on the Use of Satellite Derived Sea Surface Temperatures in Climate Applications, held in Washington, D.C.

BELL, Robert. In November, 1983 Robert commenced working at the British Meteorological Office for a period of six months. The purpose of the visit was to gain experience with a CDC Cyber 205 prior to the acquisition of a similar computer by the CSIRO.

BENNETT, John. John has participated as a committee member of the Victorian Division of the Institution of Radio and Electronics Engineers, Australia.

BIGG, Keith. Keith, at the request of the Quinghai Meteorological Service spent two weeks in China in June, 1985, delivering lectures on atmospheric chemistry and cloud physics. Keith is a member of the BAPS Working Group.

BIRD, Ian. Member, National Committee for Antarctic Research subcommittee on Meteorology, Australian Academy of Science; Programme Assessor, Engineering, Antarctic Research Policy Advisory Committee, Department of Science; Convenor, CSIRO Electronics Seminars Committee, Victoria; Advisor, Divisional Engineering, CSIRO Institute of Physical Sciences.

BOUMA, Willem. Willem joined the Division from the Australian National University, and has taken up the position of Scientific Assistant to the Chief. Willem is a member of the BAPS Working Group.

COULMAN, Chris. Chris was an invited speaker at the New Zealand Meteorological Service Conference in October 1983. After participating in the 9th International Conference on Cloud Physics at Tallinn, Estonia, Chris spent four weeks in France on a collaborative project. He then visited various establishments in the UK and the

USA discussing electromagnetic wave propagation through the turbulent atmosphere. He also accepted an invitation to participate in discussions with the Canada-France-Hawaii Telescope Board.

DAVY, Elizabeth. Liz joined the Division as Divisional Librarian from CSIRO's Central Information Library and Editorial Section (CILES).

DILLEY, Alexander. Mac Dilley attended the IPOMS Technical Meeting in the USA in June 1985.

ENTING, Ian. Ian presented an invited paper at the 6th Oak Ridge National Laboratory Life Sciences Symposium on the Global Carbon Cycle, September, 1983. Whilst in the USA he took the opportunity to visit Woods Hole and Goddard Space Centre in Knoxville, USA.

FRANCEY, Roger. Roger returned to the Division in December 1983 after secondment to the Department of Science and Technology as Director of the Cape Grim Baseline Station. Shortly before his return he attended the Life Sciences symposium at Oak Ridge where he presented a paper. He was also invited to attend a Symposium on Carbon Transfer in Atmosphere, Ocean and Terrestrial Systems at the University of California in May 1985. Whilst in the United States, Roger visited NOAA/GMCG to discuss collaborative research. As editor of Baseline Roger was in constant contact with a number of national and international scientists who have scientific instruments operating at Cape Grim. In addition, Roger was a member of the BAPS Working Group.

FRASER, Paul. During 1983 Paul was a Research Associate of the Cooperative Institute for Research in Environmental Sciences (CIRES) in Boulder, Colorado. In July 1983 he presented a paper at the Annual Meeting of the Chemical Manufacturer's Association (CMA) in Washington, D.C., in August one to the Atmospheric Lifetime Experiment (ALE) Meeting in Turnbury, Scotland, in September to the CACGP Symposium on Tropospheric Chemistry in Oxford England, and in November to the sixth ORNL Life Sciences Symposium in Knoxville, Tennessee. In November 1983 Paul returned to Aspendale.

During March 1984 he spoke at the GMCC Annual Meeting in Boulder, Colorado, and to the ALE Meeting in La Jolla, California, and hosted the subsequent ALE Meeting at Aspendale in November. In April 1985 he was an invited expert to the Global Tropospheric Chemistry Meeting in Boulder, Colorado and attended the first meeting of GAGE (Global Atmospheric Gases Experiment) in Barbados. He also presented seminars at the Massachussetts Institute of Technology, the Georgia Institute of Technology and the University of California. Paul has continued as a member of the Environmental Law Committee of the International Law Association, as a member of the BAPS Working Group and as a member of the National Health and Medical Research Council (NH&MRC)/ Australian Environment Council (AEC) Working Party on chlorofluorocarbons and alternative aerosol propellants. He has continued to present a series of lectures on atmospheric chemistry to Honours students in the Chemistry Department of the University of Wollongong.

FREDERIKSEN, Jorgen. From August 1983 Jorgen spent three months at the International Meteorological Institute in Stockholm, Sweden as the Crawfoord Fellow for 1983. In August 1984, he attended conferences in Rome, Italy and Kristineberg, Sweden. In 1984, Jorgen was awarded the prestigous David Rivett Medal for Physical Sciences for publications in the period 1973–1983, by the CSIRO Officers Association.

GALBALLY, Ian. Ian spent six weeks visiting scientific establishments in Sweden and the UK in July and August 1983. In September 1984 Ian attended a NATO Workshop on Nitrogen and Sulfur Emissions in Remote Regions of the Atmosphere held in Bermuda, as well as participating in discussions with scientists from the US and Greece. Ian also attended a meeting in Boulder, Colorado on the Global Tropospheric Chemistry Program in April 1985. Finally, Ian presented invited lectures at a Gordon Conference on Atmospheric Oxidants at New Hampton in June 1985, and called upon researchers at NCAR in Boulder and NOAA in Hampshire. Ian continues his affiliations as a member, Advisory Committee of SCOPE UNEP International Nitrogen Unit; member, National Committee on the Environment, AAS; member, BAPS Working Group; member International Ozone Commission, International Association of Meteorology and Atmospheric Physics (IAMAP); and associate editor of Journal of Atmospheric Chemistry. In 1983 and 1984, in collaboration with Greg Ayers, Ian was a lecturer at Melbourne University to graduate students.

GARRATT, John. Between 1982 and 1986, John took on the position of Chairman of a WMO Committee of Atmospheric Science group of rapporteurs on Boundary-Layer problems. This involved participation in a Workshop on Modelling of Cloud-Topped Boundary Layer at Colorado State University during April and May, 1985; John also visited NCAR during this time. John retains his affiliations as a member of the editorial board of Boundary-Layer Meteorology; member of the editorial committee, Quarterly Journal of Royal Meteorological Society, and Chairman, WMO Group of Rapporteurs on Boundary-Layer Problems. In addition John gives a lecture course on boundary-layer meteorology at Monash University to Honours and MSc students.

GRAS, John. John joined the Division in Aspendale from the Cloud Physics Laboratory in Sydney. John is to replace Keith Bigg as member of the BAPS Working Group.

HENDON, Harry. Harry joined the Division from the University of Washington, and is working in the Large-scale Dynamics group.

HOWELLS, Peter. A recent appointment to the Division, Peter was awarded a two-year CSIRO Postdoctoral Award of which the first year was spent at NCAR from April 1984 until April 1985.

HUNT, Barrie. Barrie joined the Division from ANMRC in July 1984. During 1984 and 1985 he was an Honorary Research Fellow, Department of Physics at the Latrobe University.

KING, Warren. Between 1983–85 Warren spent 18 months at NCAR. In August 1984 Warren travelled to the USSR and the UK to attend conferences and a further four weeks were spent in March/April 1985 visiting NCAR and the University of Wyoming for consultations on CSIRO software for the study of air flow around aircraft.

MANINS, Peter. Between October and November 1983 Peter spent several weeks at research institutions involved in mesoscale studies in the USA, Japan and Europe. Peter is a member of the Latrobe Valley Airshed Study Working Group; the Convenor of the LVASS Interpretation Group. From April 1985 Peter was seconded to the Victorian Government as Project Director of the Latrobe Valley Airshed Study.

McGREGOR, John. John joined the Division after the closure of ANMRC, and is working in the Small-scale Dynamics group.

O'BRIEN, Denis. A recent appointment to the Division, Denis has joined the Clouds and Radiation group.

PALTRIDGE, Garth. Garth visited scientific establishments in the USA and Japan for two weeks in July, 1983 in West Germany for two weeks in August 1983 and in the USA for two weeks in April 1984. He also attended the International Radiation Symposium in Perugia, Italy in August, 1984. In January 1985, Garth visited the University of Maryland, the Goddard Space Flight Centre and Hughes Aircraft Company for discussions on the development of space-based instrumentation. Garth continued as Chairman of the National Committee for Atmospheric Science (AAS) and as a member of the International Radiation Commission. He also presented lectures to 2nd year students at the Melbourne University (RAAF) Pt. Cook Academy.

PEARMAN, Graeme. In the two years covering the span of this report, Graeme has continued a high profile overseas. In October 1983, he attended the WMO/UNEP Conference in Austria — "1st Meeting for the Joint Assessment of the role of Carbon Dioxide in Climate Variation and their impacts". In March 1984, he was invited to represent the Division at a UNESCO Workshop on Hydrology. The WMO supported Graeme's participation in a WMO Region II and Region V meeting in Kuala Lumpur on BAPMoN operation functions and on interpretation of data. This was followed by a visit to Japan for four weeks in November/December 1984 on an Australian Academy of Science grant under the Australia-Japan Science Exchange Agreement. Also in 1984, he was an invited member at NCAR of the steering committee for a Global Troposphere Research Programme. In May 1985 he attended a conference on Carbon Transfer in the Atmosphere, Ocean and Terrestrial Systems.

In 1983 the American Geophysical Union presented Graeme with an Editor's Citation for excellence in refereeing of papers presented in the Journal of Geophysical Research, Oceans and Atmospheres. Graeme's affiliations continued: Member, WMO Commission of Atmospheric Science, Group of Rapporteurs on Carbon Dioxide and the Carbon Cycle; member, WMO Commission for Instruments and Methods for Environmental Pollution Measurement; member, Commission on Atmospheric Chemistry and Global Pollution, IAMAP; member, BAPS Working Group.

PITTOCK, Barrie. Barrie Pittock, as a member of the SCOPE-ENUWAR working group attended meetings in Sweden, India, USSR, France, Japan and England between July 1983 and May 1985. Barrie was also invited to give a series of lectures at the Catholic University of Louvain (Belgium) in June 1985 and at the New Zealand Meteorological Society Conference in Wellington. During 1983 and 1984 Barrie undertook a lecture course at Melbourne University for second year meteorology students. Since May 1984 Barrie has been a member of the Australian Academy of Science's National Committee for the Atmospheric Sciences and its sub-committee on the World Climate Research Programme, and is currently Chairperson of the AAS National Committee for the Environment. He has also served as a member of the Working Group for Solar-Terrestrial Relations of the IAMAP Commission for Meteorology of the Upper Atmosphere, and as Australian correspondent for the SCOPE project Review of the Theory, Methodology and Experience of Climate Impact Assessment.

PLATT, Martin. Martin Platt spent two weeks in the UK in December 1983, to attend a WMO Conference on the Boundary Layer over the Oceans in Reading and visit Imperial College. Martin also attended the International Radiation Symposium in Perugia, Italy and the 12th Laser Radar Conference in Aix-en-Provence in August/September, 1984. In March and April, 1985 he spent five weeks in the USA to organize and chair a WMO Workshop on the Modelling of the

Cloud-Topped Boundary Layer, and to visit NASA and other scientific establishments. Martin also was a member of the International Radiation Commission, IAMAP; and a member of the BAPS Working Group. During 1983–1985 Martin was initiator and Chairman of an ongoing Committee on the Australasian Physics of Remote Sensing which held its first Conference in Melbourne in February 1984.

PLUMB, Alan. Alan Plumb spent nine months as a visiting scientist at Princeton University between April 1983 and January 1984. In 1983 Alan was chairman of a working group writing the WMO/NASA Ozone Assessment. The committee met in October 1984 and March and July 1985 in Europe, Japan and the United States. Alan was an invited participant in a NASA meeting on Our Understanding of the Ozone Layer in Munich, June 1984 and at a workshop on The Formulation of 2D Transport Models, Boston, October 1984. Whilst overseas, Alan visited the ECMWF and Princeton University. In Japan in November 1984, he presented a paper at the International Middle Atmosphere Program Symposium. Alan is a member of the editorial committee of Pure and Applied Geophysics, an associate editor of the Journal of the Atmospheric Sciences and a member of the International Commission for Dynamical Meteorology. During 1985 Alan lectured to Honours and MSc students at Monash University.

RYAN, Brian. Brian joined the Division in Aspendale from the Cloud Physics Laboratory in Sydney. He is the Chief Co-ordinator for the Cold Fronts Research Programme.

SAWFORD, Brian. Brian presented a position paper at the American Meteorological Society Workshop during January 1984 on the Updating of Applied Diffusion Models. He also visited NCAR, Los Alamos, Alabama and Cornell University. Brian is a member of the Working Group and leader of the Non Reactive Gases Project Team of the LVASS.

SMITH, Del. In June 1985 Del inspected a number of private industry establishments in Canada and the US which are involved in the supply and manufacture of remote sensing equipment and scientific data processing activities. In addition, he visited the NOAA Environmental Satellite Data & Information Services.

STEPHENS, Graeme. Graeme took part in the ICRCCM Workshop in Frescati, Italy and attended the International Radiation Symposium in Perugia, Italy in August 1984. He is an associate editor of the Journal of Atmospheric Science and of Monthly Weather Review.

In 1983 Graeme delivered a course of lectures to meteorology students on Atmospheric Radiation at Melbourne University.

TUCKER, Brian. As Chief of the Division, Dr Tucker spent six weeks between May 1985 and June 1985 visiting various meteorological institutions in Europe and the United States and Asia. In November 1984, he was one of two Australian representatives to attend the 1st IPOMS (International Polar Orbiting Meteorological Satellites) meeting in Washington, at which Australia has observer status. Dr Tucker continued as Chairman of the Technical Advisory Group to the EPA on the Melbourne Airshed Study, member of the Latrobe Valley Airshed Study Steering Committee, and a member of the Cape Grim Baseline Air Pollution Station Management Committee.

WEBB, Eric. Member, International Association of Geodesy, Special Study Group on Electromagnetic wave propagation and refraction in the atmosphere.

Transfers

MANINS, Peter. Peter was appointed Project Director for the Latrobe Valley Airshed Study in April, 1985. Peter is employed by the Latrobe Valley Water and Sewerage Board under a three-year term of secondment from the Division.

MANTON, Mike. Mike, a member of the Division's Cloud Physics Laboratory in Sydney, took up an appointment as Chief of the Bureau of Meteorology Research Centre (BMRC) from the 1st January, 1985.

SPILLANE, Kevin. Kevin returned to the Division in early 1985 after a three-year secondment to the Division of Tropical Crops and Pastures. Subsequently he transferred to the Bureau of Meteorology to join the newly formed BMRC.

STEPHENS, Graeme. Graeme left the Division in January 1985 to take up an appointment as Associate Professor at Colorado State University.

Retirements

Dr Arch Dyer, a Chief Research Scientist and Assistant Chief of the former Division of Atmospheric Physics, retired due to ill health in July 1983. Dr Dyer had been with CSIRO for 30 years.

Three other long serving members of the Division of Atmospheric Research — **Bill Shepherd, Tony Evans** and **Derek Reid** retired during 1984. Bill and Tony were granted CSIRO Post-retirement Research Fellowships for a period of one year in 1983. Derek, an STO with the Division, retains his keen interest in climatology, and is currently engaged in doing an MSc Course at Melbourne University.

Stan Mossop, a Senior Principal Research Scientist, and **Ron Meade,** A senior Technical Officer with the Cloud Physics Laboratory also retired during the period covered by this report. Both were long-serving members of the former Division of Cloud Physics.

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PITTOCK, A.B. — Reality, stability and usefulness of Southern Hemisphere teleconnections.

First International Conference on Southerm Hemisphere Meteorology, Sao Jose dos Campos, Brazil, 31 July–6 August, 1983.

PITTOCK, A.B. — Climatic Teleconnections in the Southern Hemisphere.

ICRCCM Workshop, Frescate, Italy, 16–19 August, 1983

STEPHENS, G.L. and SCOTT, J.C. — A theoretical and observational study of radiation transfer through cumulus clouds and cloud fields.

IUGG XVIII General Assembly, Hamburg, West-Germany, 20–26 August, 1983

FREDERIKSEN, J.S. — The onset of blocking and cyclogenesis: A unified approach.

FREDERIKSEN, J.S. — Wave instability of the distorted stratospheric polar vortex at the onset of the sudden warming.

FREDERIKSEN, J.S. — Interactions of nonlinear internal gravity waves and turbulence.

PLUMB, R.A. — Invited lecture — Super-rotation in planetary atmospheres.

IAMAP-WMO Symposium on Maintenance of the Quasi-stationary Components of the Flow in the Atmosphere and in Atmospheric Models, Paris, August, 1983.

FREDERIKSEN, J.S. — Statistical dynamics of topographically forced flows in barotropic and baroclinic models.

PLUMB, R.A. — The interaction of transient eddies with the time-mean flow.

Third International Laser Conference, Melbourne, 29 August–2 September, 1983

SCOTT, J.C. — Pulse length dependence of optical inclusion damage in ADP and KD*P.

WMO Workshop on Cloud Modelling, Aspen, Colorado, September 1983

KING, W.D. — Microphysical properties of clouds on S.E. Australia.

Crawfoord Symposium on Large-scale Motions of the Atmosphere and the Sea, Stockholm, 28–29 September, 1983

FREDERIKSEN, J.S. — The role of instability in cyclogenesis, blocking, teleconnection patterns and stratospheric sudden warmings.

Fifth Conference of the New Zealand Meteorological Society, Wellington, New Zealand, 9–13 October, 1983

PITTOCK, A.B. — Invited lecture — Nuclear winter: its implications for the Southern Hemisphere.

PITTOCK, A.B. — Invited lecture — Climatic teleconnections in the context of changing boundary conditions.

New Zealand Meteorological Service Annual Meteorological Conference, Wellington, 18–20 October, 1983

MCGREGOR, J.C. — Limited area modelling.

TUCKER, G.B. — The observed atmospheric response to a variation in globally incident solar radiation.

TUCKER, G.B. — Research programs in the new CSIRO Division of Atmospheric Research

Sixth ORNL Life Sciences Symposium on the Global Carbon Cycle, Knoxville, U.S.A., 31 October–2 November, 1983

ENTING, I.G. and G.I. PEARMAN — Invited lecture — The use of observations in calibrating and validating carbon cycle models.

FRANCEY, R.J. — Invited lecture — Carbon isotope measurements in Baseline air, forest canopy air and plants.

FRASER, P.J., W.P. ELLIOTT and L.S. WATERMAN — Invited lecture — Atmospheric CO_2 record from direct chemical measurements during the 19th Century.

Eighth Australasian Fluid Mechanics Conference, Newcastle, N.S.W., 28 November–2 December, 1983

SAWFORD, B.L. — A Lagrangian statistical model of turbulent concentration fluctuations.

NCAR Symposium on aircraft-induced sampling problems. Boulder, Colorado, December, 1983

KING, W.D. — Airflow and particle trajectories around aircraft fuselages.

American Meteorological Society Workshop on Updating Applied Diffusion Models, Clearwater, Florida, 24–27 January, 1984

SAWFORD, B.L. — Invited paper — Numerical simulations of diffusion: mean and fluctuating concentration fields and modelling uncertainty.

International Conference on Mesoscale Meteorology, Melbourne, 6–10 February, 1984

BAINES, P.G. and B.P. LEONARD — A mechanistic model of the prefrontal trough.

BAINES, P.G. — A general method for determining topographic effects in hydrostatic stratified flow of finite depth.

COULMAN, C.E. — Two southerly buster events — structure over the ocean.

GARRATT, J.R., W.L. PHYSICK and R.K. SMITH — Mesoscale aspects of cold fronts in southeast Australia.

MANINS, P. — Concomitant research from the Latrobe Valley airshed study.

PHYSICK, W.L., W.K. DOWNEY, A.J. TROUP, B.F. RYAN AND P.J MEIGHEN — Mesoscale observations of a pre-frontal squall line.

RYAN, B.F. — Cold fronts research programme — mesoscale research on a united front.

RYAN, B.F., W.D. KING and S.C. MOSSOP — The microphysical properties and airmotions associated with a cold front.

First Australasian Conference on the Physics of Remote Sensing of the Atmosphere and Ocean, Melbourne, 13–16 February, 1984.

BARTON, I.J. — Modelling of atmospheric absorption in the infrared windows.

GARRATT, J.R. and N.A. SHAW — Observations of winds at a cold front using Doppler acoustic radar.

PALTRIDGE, G.W. — The current status of the International Satellite Cloud Climatology Project (ISCCP).

PLATT, C.M.R., A.C. DILLEY, and J.C. SCOTT — Lidar sounding of clouds.

Clean Air Conference, Melbourne, 7–11 May, 1984.

TUCKER, G.B. — Plenary lecture — The global CO_2 problem.

ELSWORTH, C.M. and I.E. GALBALLY — Accurate surface ozone measurements in clean air: Fact or fiction.

EVANS, L.F.T., I.A. WEEKS and A.J. ECCLESTON — A smog chamber study of Melbourne's photochemical pollution.

GALBALLY, I.E. — Ozone and nitrogen oxides in background air over south eastern Australia.

SAWFORD, B.L. — Lagrangian statistical modelling of turbulent dispersion.

NASA-WMO Meeting on Current Issues in our Understanding of the Stratosphere and the Future of the Ozone Layer, Feldafing, West-Germany, June 1984

PLUMB, R.A. — Invited lecture — The theoretical basis of two-dimensional transport modelling.

First Australian TOGA (Tropical Ocean — Global Atmosphere Meeting, Hobart, 9–10 July, 1984

WEBB, E.K. — Development of an air-sea bulk transfer relationship.

Australian Mathematical Society, Conference on Inverse Problems in Applied Mathematics, Kensington, N.S.W., 18–19 July, 1984

ENTING, I.G. — Inverse problems in carbon cycle modelling.

Conference on Australian Rainfall Variability, Arkaroola, S.A., 6–8 August, 1984

HUNT, B.G. — Climatic research the contributions from numerical modelling.

PITTOCK, A.B. — Australian rainfall variations and teleconnections in the context of changing boundary conditions.

PITTOCK, A.G. and H.A. NIX — Effects of temperature and rainfall changes on Australian biomass productivity.

International Laser Radar Conference, Aix-en-Provence, France, 13–17 August, 1984

PLATT, C.M., A.C. DILLEY, and J.C. SCOTT — Optical properties of cirrus cloud measured with lidar and infrared radiometry.

Ninth International Cloud Physics Conference, Tallinn, Estonia, 21–28 August, 1984

COULMAN, C.E. — Raining and non-raining cumuli: The influence of cloud properties and environment conditions.

International Radiation Symposium, Perugia, Italy, 21–29 August, 1984

BARTON, I.J. — Infrared absorption coefficients obtained from satellite data.

PLATT, C.M. — Extinction in clouds.

STEPHENS, G.L., C.M. PLATT and J.C. SCOTT — A theoretical and observational study of radiative transfer through cumulus clouds and cloud fields.

Workshop on the Dynamics of Long Waves in the Atmosphere, Kristineberg, Sweden, 22–24 August, 1984

FREDERIKSEN, J.S. — Instability theory of blocking and teleconnection patterns.

IBM Workshop on Global Scale Anomalous Circulation in the Atmosphere and Blocking, Rome, 27–30 August, 1984

FREDERIKSEN, J.S. — Instability theory and nonlinear evolution of blocks and mature anomalies.

Commission on Atmospheric Chemistry and Global Pollution Symposium on Tropospheric Chemistry, Oxford, 28 August–3 September, 1983

GALBALLY, L.E. and C.R. ROY — Nitric Oxide Exhalation from a Pasture Soil.

International Ozone Symposium, Thessoloniki, Greece, 3–7 September, 1984

GALBALLY, I.E. — Measurements of ozone in tropospheric air at Cape Grim (41°S) and nearby locations.

GALBALLY, I.E., C.R. ROY, R.S. O'BRIEN, B.A. RICLEY, D.R. HASTIE, W.F.J.EVANS, C.T. McELROY, J.B. KERR and P. HYSON — Trace gases in the southern hemisphere stratosphere.

Nato Workshop on Nitrogen and Sulfur Cycling in Remote Regions of the Atmosphere, St Georges, Bermuda, 7–13 October, 1984

GALBALLY, I.E. — Emissions of Nitrogen Compounds in Remote Regions of the Atmosphere.

National Space Engineering Symposium, Canberra, 10–11 October, 1984

HILL, R.H. — A Manchester Code decoder.

World Meteorological Organization Seminar on BAPM.N Operational Functions and on Interpretation of Data, Kuala Lumpur, 15–20 October, 1984

PEARMAN, G.I. — One of four lectures giving a 1-week course to monitoring station operators.

Conference on Measurement, Instrumentation and Digital Technology, Melbourne, 31 October–2 November, 1984

BIRD, I.G., C.G. WALLEY and J.W. BENNETT — Tracking antenna for NOAA Meteorological satellites.

NASA-WMO Workshop on the Formulation of Two-dimensional Transport Models, Boston, October 1984

PLUMB, R.A. — Invited lecture — Transport parameterization in 2-D models.

The Scientific Application of Baseline Observations of Atmospheric Composition, Aspendale, 7–9 November, 1984.

AYERS, G., J.P. IVEY and H.S. GOODMAN — Excess sulfate and methanesulfonate in aerosol samples from Cape Grim.

BIGG, E.K. — Baseline observations of cloud condensation nuclei at Cape Grim, Tasmania.

ENTING, I.G. — Preliminary studies with a two-dimensional model using transport fields from a GCM.

FRANCEY, R.J. — Cape Grim carbon isotope measurements — a preliminary assessment.

FRASER, P.J., P. HYSON, and R.A. RASMUSSEN — Methane and carbon monoxide in the Southern hemisphere.

STEELE, L.P., P.J. FRASER, R.A. RASMUSSEN, M.A.K. KHALIL, A.J. CRAWFORD, T.J. CONWAY and R.H. GAMMON — Global distribution of atmospheric methane and aspects of interpretation of these data.

GALBALLY, I.E. — Long term changes in atmospheric nitrous oxide.

GRAS, J. and A. ADRIAANSEN — Concentration and size variation of condensation nuclei.

PEARMAN, G.I and P. HYSON — Global transport and interreservoir exchange of CO_2 with particular reference to the effect on concentration and isotopic distribution.

PLATT, C.M.R. — The interpretation of atmospheric turbidity measurements.

PLUMB. R.A. — The zonally-averaged transport characteristics of a GCM and a test of the validity of "K-Theory" as a parameterization of eddy transport.

THOMPSON, M.L., G.I. PEARMAN, I.G. ENTING, and P. HYSON — Interannual variations of atmospheric CO_2 concentration.

Middle Atmosphere Program Symposium, Kyoto, Japan, November 1984

PLUMB, R.A. — The zonally-averaged transport characteristics of a general circulation model.

CRAIG, R.L., R.A. VINCENT and R.A. PLUMB — On the interaction between the quasi-two-day wave and the mean flow.

Symposium on Ion chromatography, University of N.S.W., 21st November, 1984

GILLETT, R.W. — Ion Wavelength U.V. Detection in Ion chromatography.

American Geophysical Union, Fall Meeting, San Francisco, 3–7 December, 1984

BAINES, P.G. — Stratified flow over two-dimensional topography in fluid of infinite depth — a laboratory simulation.

Australian Physical Oceanography Conference, Hobart, 10–15 February, 1985

BAINES, P.G. — Stratified flow over two-dimensional topography in fluid of infinite depth — a laboratory simulation.

BARTON, I.J. and G.W. PALTRIDGE — Satellite measurement of sea surface temperature.

WEBB, E.K. — Sea-air transfer of CO_2: A feasible approach to measurement.

RACI—Victorian Branch: Computers in Chemistry Symposium, Melbourne, 28 February, 1985

BOUMA, W.J. — Invited lecture — Molecular orbital calculations and organic chemistry.

Australia and New Zealand Environmental Effects of a Nuclear War, Melbourne, 28–29 March, 1985.

BIGG, K. and W.J. MEGAW — Particles in bushfire smoke in Western Australia.

GALBALLY, I. — Smoke and dust from nuclear explosions.

MANINS, P. — Cloud heights and stratospheric injections resulting from a thermonuclear war.

PALTRIDGE, G.W. — Let's not get too excited.

PITTOCK, A.B. — The atmospheric effects of nuclear war: An overview.

PITTOCK, A.B. and H. NIX — Effects of nuclear winter scenarios on Australian biomass productivity.

Third Australasian Conference on Heat and Mass Transfer, Melbourne, May 1985

WEBB, E.K. — On the dependence of Nusselt number on Rayleigh number for convection in a horizontal fluid layer.

Australian Academy of Science Symposium: The Changing Earth: An Australian Perspective, Canberra. May, 1985

PEARMAN, G.I. — Invited lecture — The changing atmosphere: Chemical weather and climate.

Gordon Conference: Environmental Sciences — Air, New Hampton, New Hampshire, 24–28 June, 1985

GALBALLY, I. — A southern hemispheric view of tropospheric ozone.

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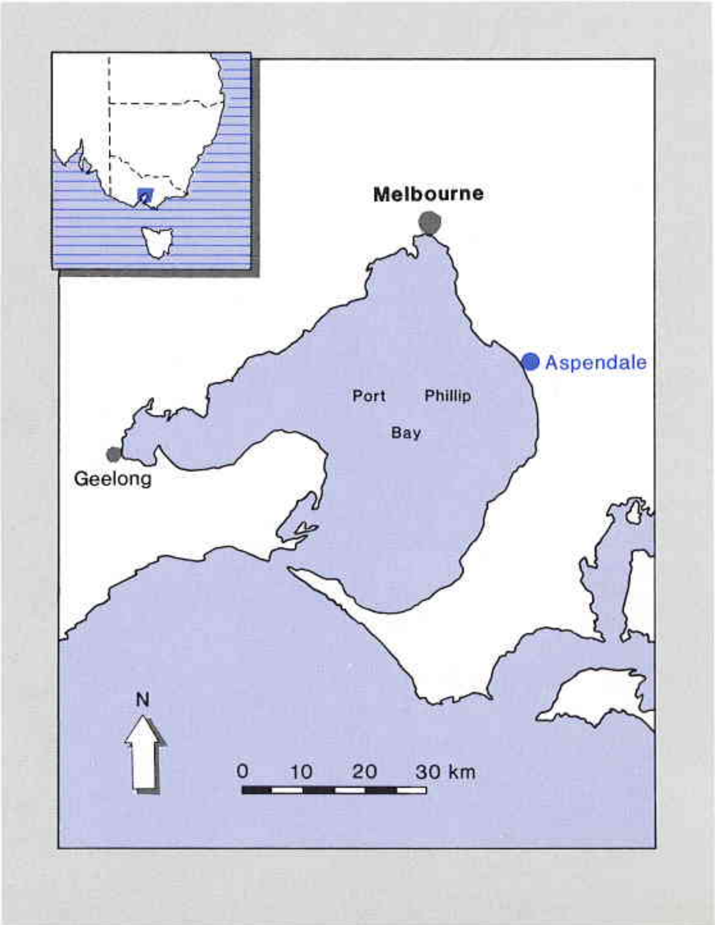

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