CSIRO

Division of Atmospheric Research
Research Report 1990 - 1992

A Division of the Institute of Natural Resources and Environment

THE DIVISION OF ATMOSPHERIC RESEARCH

Mission:	To solve significant problems concerning the physics, dynamics and chemistry of the atmosphere over the Australian region, and of the globe insofar as it affects the Australian region. To provide the best possible scientific advice on problems and issues involving the atmosphere.
Founded:	1946
Location:	Aspendale, Victoria
Size:	150 staff
Research Programs:	Atmospheric Pollution and Applied Meteorology Global Atmospheric Change Radiation and Climate Water Resources and Climate Change
Major facilities:	Automated non-methane hydrocarbon sampling equipment CSIRO System for Interactive Data Analysis (CSIDA) Geophysical Fluid Dynamics Laboratory Global Atmospheric Sampling Laboratory (GASLAB) Ice Core Extraction Laboratory (ICELAB) Lidar and radiometers Numerical models of the atmospheric boundary layer and the global climate system Precipitation Chemistry Laboratory Wind tunnel
Funding:	1990–91, $13.3 million 1991–92, $12.7 million
Publications:	363 refereed publications (1990–92) Biannual newsletter, the *DAR Bulletin* Biennial Research Report
Major sources of external funds:	Australian Water Resources Advisory Council Bureau of Meteorology (Cape Grim Baseline Air Pollution Station) Conservation Commission of Northern Territory Department of Agriculture and Rural Affairs (Vic.) Department of the Arts, Sport, the Environment and Territories Department of Industry, Technology and Commerce Department of Primary Industries and Energy Electricity Commission (WA) Environment Protection Authority (Vic.) Environment Protection Authority (WA) Melbourne Water State Electricity Commission (Vic.) State Pollution Control Commission (NSW) Wool Research and Development Fund

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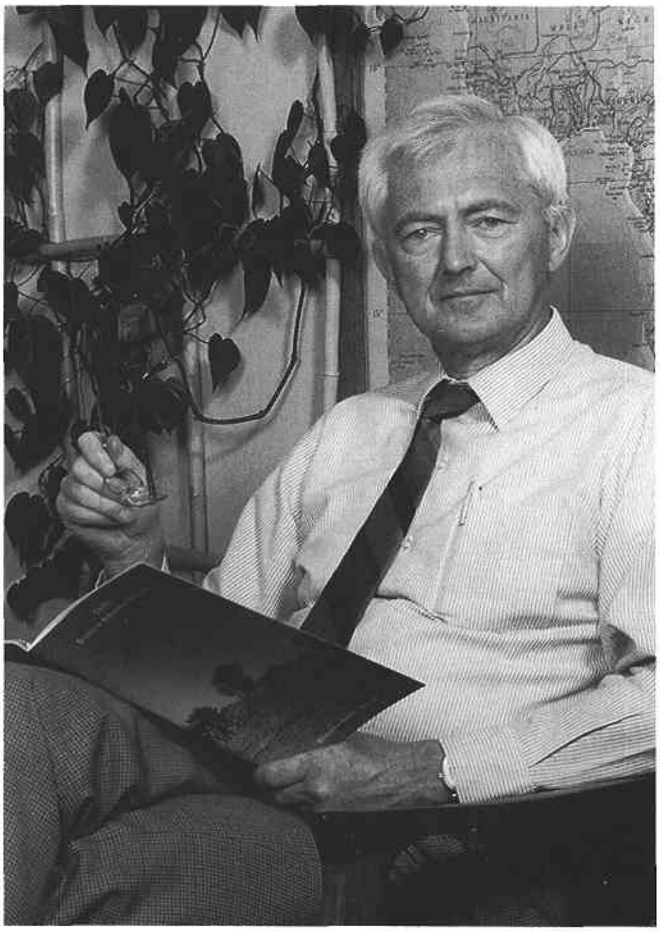
Cover photograph
Volcanic sunset over Port Phillip Bay, 19 July 1991. The eruption of Mt Pinatubo in the Philippines injected massive quantities of dust and sulfur dioxide into the stratosphere. The first recording of volcanic material over Australia was made at the Division using a lidar, just over a month after the main eruption. The vivid long-lasting sunsets witnessed across much of the country were due to high altitude dust scattering sunlight coming from beyond the horizon.

FOREWORD



Dr Brian Tucker

This will be my last foreword in a Divisional Research Report because the new Chief, Graeme Pearman, takes over the reins when I retire on 1 November 1992. Effectively Graeme and I have been working in harness for several years and it is a pleasure to hand over responsibility to someone who has played a major part in developing the strong scientific skills and achievements in the Division over the past decade or more, and who has a clear progressive vision for the future.

The Division has recently been reviewed from the point of view of future directions. This review comments favourably on the scientific platforms developed which can act as springboards into the future. It made particularly favourable remarks about the new Environmental Consulting and Research Unit, and the advances in science and application of air pollution meteorology (including chemistry) associated with that program. National and international interactions already established bear witness to the exciting future for this general area of research. As a sequel to a CSIRO Air Quality Workshop held during the year at the Division, an international workshop on Air Pollution Problems and Modelling is being planned for March 1993 involving representatives from industry and science from Australia, New Zealand and South-East Asian countries.

Another feature noted by the Review and one which is attaining increasing international recognition is the hierarchy of general circulation models developed in our Climate Research Laboratory (mentioned in the 1988–1990 Research Report). This strong facility is an essential component of an attack on the broad climate variability and climate change problem which also involves dynamical, physical and chemical research in other associated programs in the Division. It represents an integrated research philosophy which few, if any, other atmospheric science research institutions in the world possess to the same extent.

I am tempted to dwell on a number of successful and promising scientific initiatives developed at the Division over the past five years or so: these would include the Global Atmospheric Sampling Laboratory, extreme precipitation modelling and its relevance to probable maximum precipitation estimates, acid rain studies in Australia and South-East Asia, outstanding theoretical research into global dynamics, and a new atmospheric boundary layer textbook. But such a list could be extended much further, and adequate coverage is well beyond the scope of this Foreword. I shall simply end by saying that it is with some pride that I leave the Division in such a sound and progressive state. It will obviously continue to play a significant part in Australia's future and in the international development of atmospheric science.

Dr Brian Tucker
Chief of Division

INTRODUCTION

Research in the national interest

The behaviour of the atmosphere through weather, climate and pollution affects all Australians, including much of our socio-economic activity and our natural environment. In turn, there is increasing awareness of how human activities can have a significant impact on the atmospheric environment.

The Division's research effort is designed to be in the national interest, of benefit to the nation as a whole.

Australia's unique position

The significance of atmospheric research in Australia in general, and that carried out by the Division in particular, is closely linked to Australia's unique position as a large and isolated continent in the southern hemisphere. The country encompasses a wide range of climatic regimes, while the climate itself is highly variable. Strategic research on the southern hemisphere atmosphere and oceans is essential for a successful application of improved understanding for the benefit of Australia. Hence, much of the Division's research is focused on issues unique to Australia and the southern hemisphere, and involves a wide range of collaborative activities with other research organisations here and overseas.

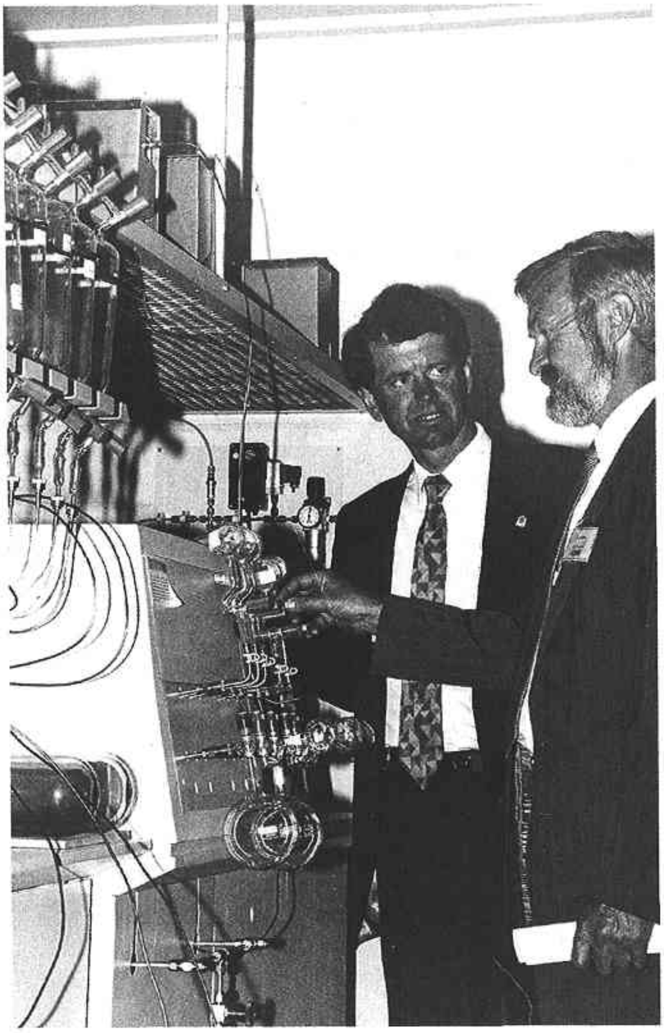
International role

The atmosphere knows no national boundaries, and its dynamical behaviour and many of the associated physical mechanisms are global in nature. This has significant consequences for the scope of the Division's research activities. These activities need to take a global perspective in order to properly address the scientific issues, and to allow the appropriate implications to be assessed for the benefit of Australia.

Research Programs

Scientific activities are carried out within four research Programs.

The *Atmospheric Pollution and Applied Meteorology Program* studies factors which influence air pollution and bushfires. The focus is on identifying sources of pollution and the way in which it is formed, transported and dispersed. The interaction between winds and geographical features is an important aspect of this work.



CSIRO's Chief Executive, Dr John Stocker (left), and Leader of GASLAB, Dr Roger Francey, at the official opening of the new laboratory

Changes in the chemical composition of the atmosphere are occurring both regionally and globally. At a global level there is now strong evidence that these changes are likely to bring about significant modifications to climate as a result of the enhanced greenhouse effect. Research in the *Global Atmospheric Change Program* seeks to discover why the chemistry of the atmosphere is changing and how it is likely to change in future.

As the earth's weather is driven by radiation from the sun, a precise understanding of the way solar radiation interacts with the atmosphere is essential to our understanding of weather and climate. The *Radiation and Climate Program* uses remote sensing

The June 1992 meeting of the Divisional Advisory Committee. From left to right: Dr Brian Tucker; Dr Brian Robinson; The Hon. Fred Chaney; Assistant Chief, Dr Graeme Pearman; Mr Alan Rainbird; Dr Willem Bouma; and Institute Director, Dr Roy Green.

instruments on board satellites, planes and on the ground to collect information about the atmosphere, the oceans, and land surfaces.

The *Water Resources and Climate Change Program* focuses on the way in which climate influences the water budget. Practical means of forecasting droughts are being devised and research is improving our understanding of storms and rain-bearing systems. There is a strong emphasis on developing and refining computer models of the atmosphere. Of key interest are the likely changes to our climate caused by the enhanced greenhouse effect.

The Divisional Advisory Committee

Since 1984, the Divisional Advisory Committee has provided valuable feedback and advice to the Division on policy issues and on the appropriateness and direction of our research activities.

The composition of the Advisory Committee at its most recent meeting (26 June 1992) was:

Chairman
Mr Alan Rainbird
Former Deputy Chief Executive
Civil Aviation Authority

The Hon. Fred Chaney, MP
Federal Member for Pearce
Shadow Minister for Sustainable Development and the Environment

Dr Doug Gauntlett
Deputy Director,
Bureau of Meteorology

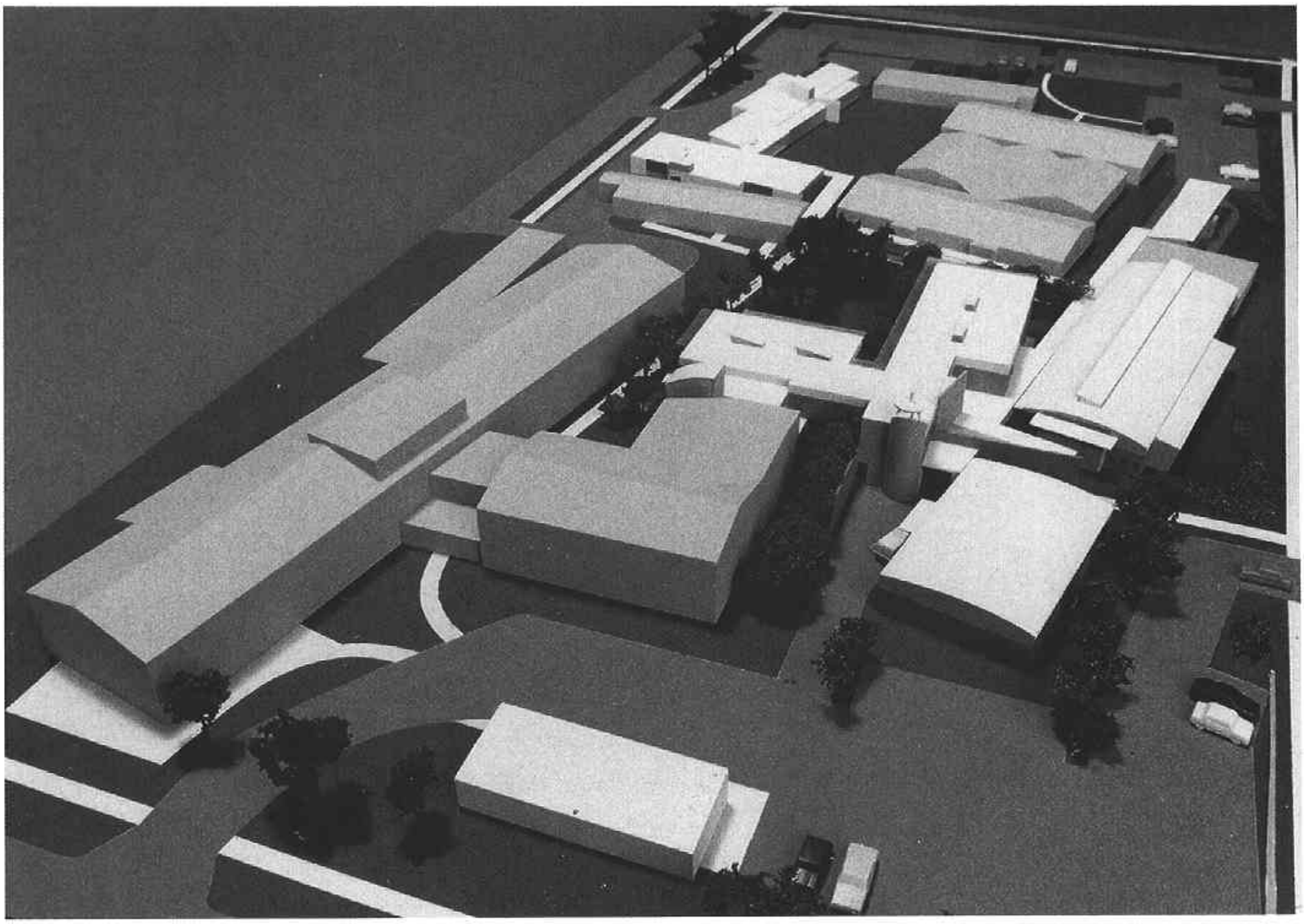
Dr Ian McPhail
Executive Director,
Commonwealth Environment Protection Authority

Dr Brian Robinson
Chairman,
Environment Protection Authority (Victoria)

Mr Terry Silverson
Former Executive Director,
ICI Australia Ltd

Ex-Officio Member
Dr Brian Tucker
Chief of Division

Secretary to the Committee
Dr Willem Bouma
Executive Assistant, Science Policy
Division of Atmospheric Research



A model showing the site's appearance following completion of the building project.

Site redevelopment

The Division is about to commence a major redevelopment of its Aspendale site. CSIRO has provided $3.5 million for the construction of new facilities and the refurbishment of existing buildings.

The Division will gain new laboratory facilities as well as a new library, lecture theatre, electronics workshop and canteen. Administrative and executive offices will also be constructed.

Stage one of the project will be a laboratory for development of remote sensing instruments including the atmospheric pressure sensor and a new lidar.

Current laboratories in the main building will then be modernized and expanded. These laboratories will continue to be used for research into climate and climate change, ozone depletion, remote sensing applications, atmospheric chemistry and acid rain.

The redevelopment is expected to be completed by February 1994.

Atmospheric Pollution and Applied Meteorology

Vision

To undertake world-class research and development in atmospheric pollution and regional meteorology.

Objectives

- To increase knowledge of surface, orographic and boundary-layer processes in order to improve the analysis and prediction of urban and regional air pollution.
- To apply knowledge gained to customer-oriented projects, primarily through an Environmental Consulting and Research Unit (ECRU) and a Rainwater Study Unit.

Dr John Garratt, Program Leader

Introduction

The nature and severity of air pollution depend on the source, chemical transformations of pollutants, transport by local and regional winds, dispersion by turbulence in the atmospheric boundary layer, and local topography. The Program aims to improve understanding of each of these factors.

Research includes theoretical analysis, numerical model development and simulations, laboratory experiments and field measurements. Applied and consulting work rely on numerical models of the atmosphere, dynamical and chemical pollution models, field work and data analysis.

There are two complementary research streams — atmospheric pollution and applied meteorology.

Atmospheric pollution research involves strategic research focused on theoretical and experimental studies of turbulent dispersion in the atmospheric boundary layer. Major regional studies are being undertaken.

Applied meteorology studies incorporate the development and evaluation of surface, boundary-layer and orographic parameterisation schemes in numerical models used for pollution and climate studies.

Turbulent dispersion

Turbulence is a complex phenomenon which affects all atmospheric processes, particularly dispersion.

The Division has developed sophisticated computer models of dispersion. New approaches to air pollution studies are based on up-to-date knowledge and measurement.

Theoretical studies

Lagrangian theories are being used to better understand the statistics of dispersion in the atmosphere.

Advances in theory are leading to a variety of direct benefits. These include improved modelling of the transport of pollutant emissions and better estimates of the uncertainty of such modelling. Estimates of short-term peak concentrations are being applied to odour modelling, and the Division has developed the ability to model the interaction of multiple pollution sources.

Experimental studies and field work

Laboratory experiments play an important role in bridging the gap between idealized situations that can be studied theoretically and the complex conditions encountered in the atmosphere.

The Division's 4000-litre modelling tank provides detailed data on the structure and growth of the convective boundary layer. It also gives information about the effect of boundary-layer turbulence on

Dr Brian Sawford and Dr Michael Borgas examine results from their dispersion model.

buoyant plumes and the interaction of these plumes with the inversion layer.

Wind-tunnel measurements have provided high quality data with which to develop theories and statistical dispersion relationships for concentration fluctuations in particular.

Ultimately, theoretical and laboratory studies depend on field data for verification. An intensive field study of dispersion from a power station under strongly convective conditions was completed at Tarong, Queensland in 1989.

During the study, the Divisional lidar was used to measure the three-dimensional distribution of plume concentration. These data are now being used to assess model simulations.

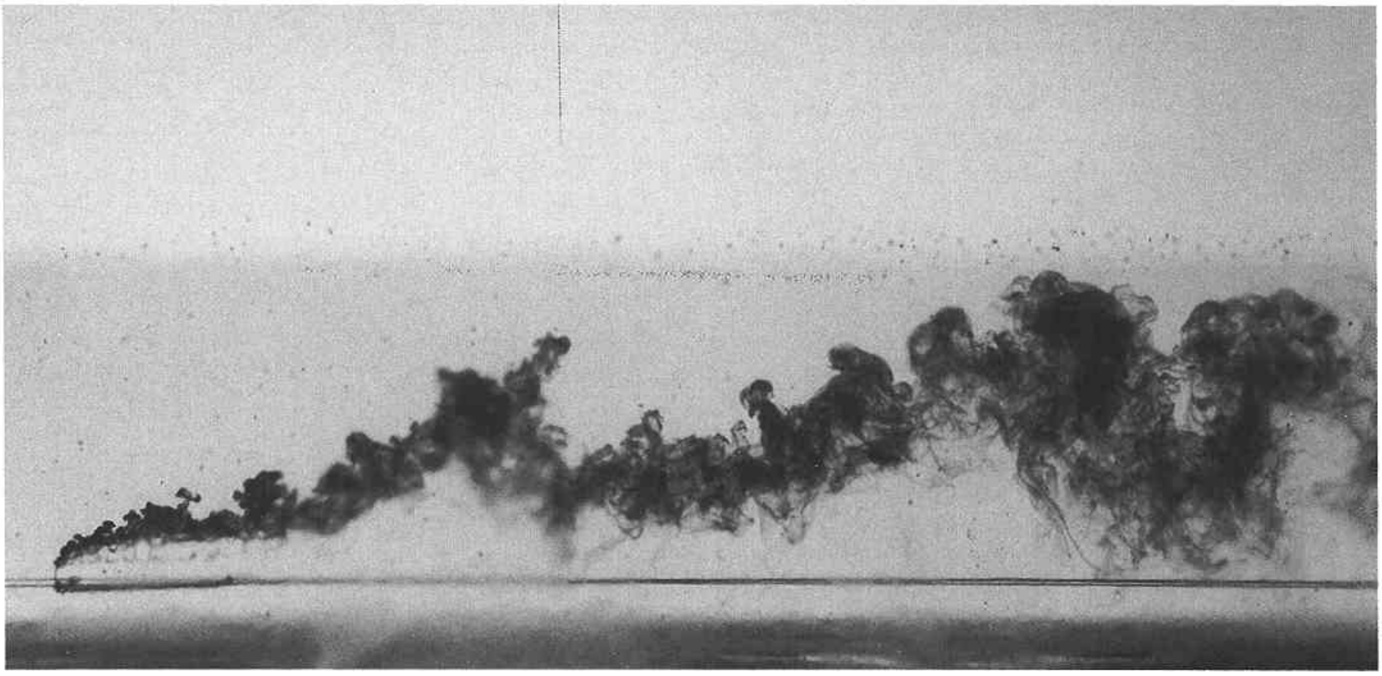
More details of the Tarong power station experiment can be found in the Division's 1988–1990 Research Report.

Air Pollution Meteorology

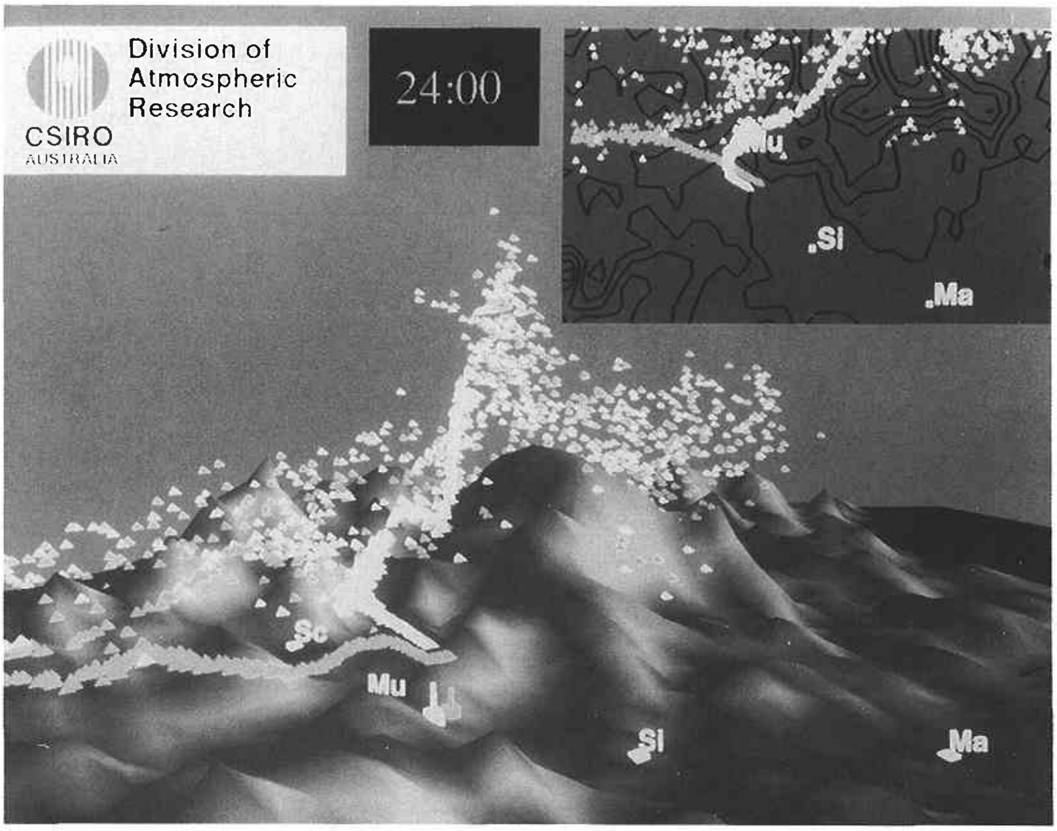
Numerical modelling

Numerical modelling complements the theoretical and experimental techniques used for studying regional wind flows in complex conditions.

The Division has developed a prognostic numerical wind-field model to describe regional winds as they vary throughout the day. As well as its applications to air pollution studies, the model is used for climate investigations, nested within global general circulation models. (More details of this limited-area model are presented in the Water Resources and Climate Change Program section of the Report). A Lagrangian particle model, which accurately describes the dispersion of pollutants, has been coupled to the wind-field model to produce a highly sophisticated numerical



Studying plume dispersion in a laboratory water tank. This is an upside-down down view of the tank. Dye injected from a moving nozzle represents a smoke plume. The atmospheric convective boundary layer is simulated by low-density salt solution sitting above a concentrated solution. Buoyancy is generated by a saline solution diffusing through a membrane at the top of the tank.



A computer-generated simulation, using LADM, showing dispersion of two plumes from potential power station sites in a mountainous region of Australia.

prognostic wind and pollutant dispersion model. The Lagrangian Atmospheric Dispersion Model (LADM), is well-suited to studies of hilly, coastal areas and other complex regions, particularly where measured data are scarce.

LADM has already been used extensively throughout Australia for research and for industry-funded projects. Potential applications of LADM are numerous. They include emergency response to industrial accidents, real-time emission controls on industry, siting of new power stations and bushfire control.

Air pollution consultancies

The Environmental Consulting and Research Unit (ECRU) has been established within the Division to deal with commercial activities. ECRU staff include scientists experienced in air pollution chemistry and dispersion, meteorology and numerical modelling.

In a project for the New South Wales Electricity Commission, ECRU was asked for advice on locating a possible new power station so as to minimise air pollution problems.

Simulations with LADM involved modelling a case-study day and comparing the results with observations, determining a worst-case scenario for present power station emissions, and producing a worst-case scenario under which the impact of a new emitter at each of four proposed sites was evaluated.

Results of the investigation were presented as a report and as a video.

Modelling of emissions from the existing power stations included morning fumigation, high midday pollution concentrations caused by convective mixing, and inland penetration of the sea breeze. Clearly evident were different plume directions depending on whether they were caught in the sea breeze or were high enough to be transported by the gradient wind.

On behalf of the Western Australian Energy Commission and the Environmental Protection Authority, ECRU has investigated how the Kwinana Power Station could comply with a new State Environment Protection Policy.

ECRU has also been involved in air pollution assessments for the Newcastle region of New South Wales, and for Gladstone in Queensland.

Recently, LADM was used to predict smog circulation for the Perth Airshed Photochemical Study. The predictions showed pollutant build-up due to recirculation over Perth. This recirculation is due to the afternoon onset of a sea breeze which carries

An electron microscope enables Dr John Gras to determine the size and nature of aerosol particles collected during a study of visibility reduction in Melbourne.

pollutants inland. In the evening, the breeze weakens, and polluted air moves back over the city.

In the Philippines, the World Health Organization sponsored a study that led to the construction of an air pollution model showing how pollutant concentrations vary across Manila. The model allows assessments to be made of the way in which motor vehicles, industry and power stations contribute to air pollution.

In Japan, a salt-stratified water-tank towing facility for modelling stable air flow has been established with Divisional assistance at the National Research Institute for Pollution and Resources in Tsukuba.

Air quality and visibility

Melbourne Aerosol Study

In large cities, aerosol particles in the atmosphere often significantly reduce visibility by scattering and absorbing light. In Melbourne, visibility problems occur most frequently during autumn because of stable atmospheric conditions.

In the past, little has been known about sources of aerosol particles in Melbourne. The Melbourne Aerosol Study, a collaborative project with the Victorian Environment Protection Authority, was designed to improve our knowledge. The study focussed on the chemistry and microphysics of aerosol particles.

On days of low visibility, particles were collected from two sites close to the city. Analysis showed that particles responsible for reducing visibility were small, typically with radii between 0.1 and 0.15 micrometres. Carbon was the main element present, accounting for 66% of the mass.

Motor vehicles, secondary production and smoke were the main sources of atmospheric aerosol particles. Most of the smoke is likely to have come from domestic wood burning. This form of heating consumes over 400 000 tonnes of wood each year in Melbourne. Burning of leaves also adds to the smoke problem.

Photochemical smog

Naturally occurring hydrocarbons

Studies of Melbourne air have shown that photochemical production of ozone will only occur when hydrocarbon concentrations are sufficiently high. Hydrocarbons come from anthropogenic sources such as motor vehicles, and natural sources such as plants.

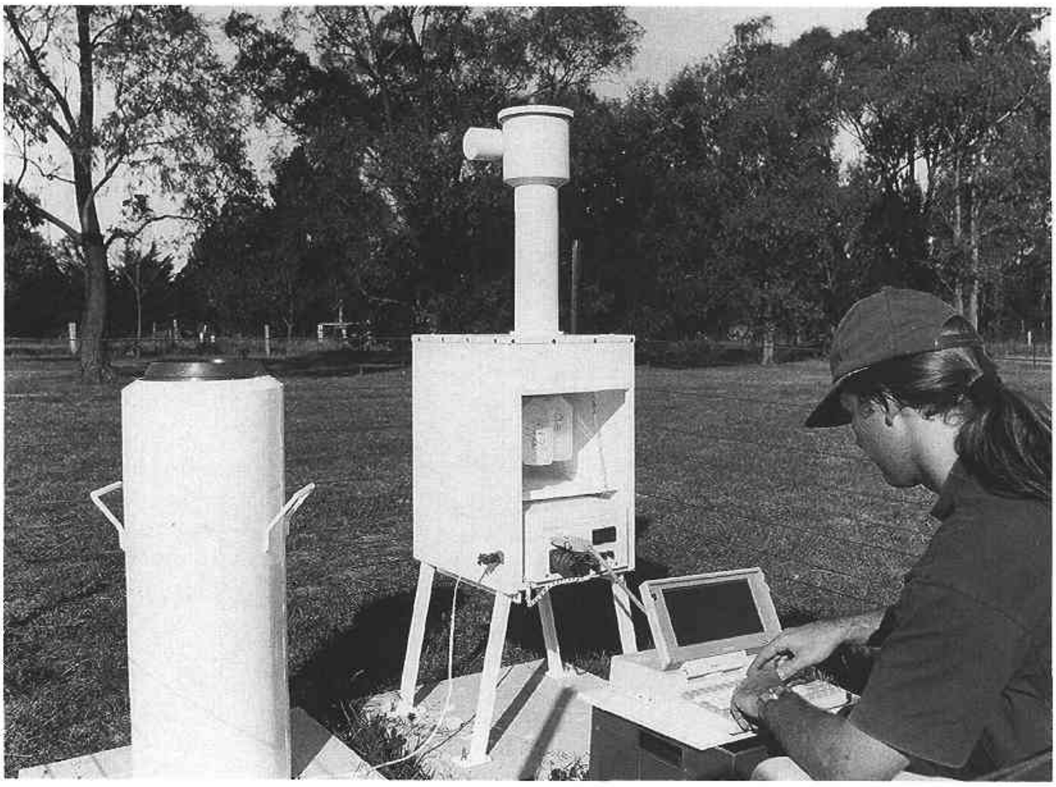
To control smog, we need to know the contribution that plants make to the levels of reactive hydrocarbons in the air.

In a project with the Environment Protection Authority of Victoria, air samples were collected in a large park on the outskirts of the city. The park was forested, with eucalypts, wattles, and tea-trees. These native plants release isoprene and terpenes, which are far more reactive than most anthropogenic hydrocarbons.

Analysis showed that, for much of the collecting period, isoprene made a major contribution to the hydrocarbon reactivity of the air. This suggests that the compound can contribute significantly to Melbourne's photochemical smog problems.

Vehicle emissions

Since 1986, new cars in Australia have had catalytic converters in their exhaust systems. These converters reduce the amounts of oxides of nitrogen, carbon monoxide and unburnt petrol escaping into the air.



Paul Selleck uses a laptop computer to download rainfall data from an automatic rainwater sampler designed and built at the Division.

In 1983–84, a detailed study was undertaken of Melbourne's air quality. To assess the impact of catalytic converters, a similar study was carried out in 1990.

Measurements were made of air collected in the central business district. The results show that, compared to 1983–84, concentrations of non-methane hydrocarbons and carbon monoxide have dropped by 45% and 37% respectively. Concentrations of oxides of nitrogen and methane have remained essentially unchanged.

Analysis of exhaust gases shows that catalytic converters are increasing the proportion of methane and other alkanes while decreasing the proportion of olefins, acetylene and aromatics.

This study was a collaborative project with the Environment Protection Authority of Victoria.

Rainwater composition

Coal-burning power stations in Victoria's Latrobe Valley supply most of the State's electricity. A major ten-year investigation of air quality, the Latrobe Valley Airshed Study, concluded in 1988. Following this Study, the issue of acidic deposition due to emissions of sulfur dioxide and oxides of nitrogen was raised.

A two-year rainwater composition study, initiated jointly by the Division and the State Electricity Commission of Victoria, began in early 1990. Field sampling was carried out at a small number of sites within the Valley.

The conclusion is that power stations are not contributing significantly to rainwater acidity. In fact, rainwater acidity levels throughout the Latrobe Valley are from ten to one-hundred times lower than those found capable of harming plants and animals by direct contact.

However, rainfall is just one way in which acidic particles can reach the ground. Dry deposition also can occur, in which sulfur dioxide and other acidic gases and aerosols come into direct contact with the ground. Neither the relative importance of dry deposition of acidic particles, nor an investigation of long-range transport of emissions, was included in the study.

To carry out the sampling program, CSIRO designed and built a sophisticated automatic rainwater sampler. Specially suited for use in remote locations, the sampler collects and stores rainwater for subsequent chemical analysis. The instrument is now being marketed around the world by the Australian company Ecotech Pty Ltd.

Two rainwater studies in New South Wales for Pacific Power have followed the Latrobe Valley work. The Division has assessed rainwater composition, atmospheric gas concentrations and data on surface water and soil properties in the Hunter Valley. A three-year study has just begun of rainwater composition and acidic deposition in the western coalfields, 130 kilometres from Sydney.

Projects have also been completed in South-East Asia. A report on acid deposition has been provided to Tenaga Nasional Berhad (the Malaysian National Electricity Authority). Rainwater, gas and aerosol sampling have been undertaken in Jakarta and around the Suralaya power station in Western Java.

Applied meteorology

The climate of a region, and its day-to-day weather have a major influence on mixing and transport of pollutants.

The most important chemical and dynamical processes affecting air quality occur in the atmospheric boundary layer. This is the lowest part of the atmosphere, in which air is well mixed. The top of the boundary layer can range from 50 metres to 2 kilometres above the ground.

Boundary-layer structure is related to the underlying surface and to orographic features. The Division's mesoscale models — used for local and regional pollution studies — and general circulation models — used for studying regional and global climate — rely on accurate representations of the surface, the atmospheric boundary layer, and orography.

Modelling biospheric–atmospheric interactions

General circulation models tend to simplify the complex exchanges of gases and energy between soil surfaces, plants and the atmosphere. Thus, much effort is being made to develop and evaluate a physically-sound biospheric scheme, incorporating soil and canopy processes, surface hydrology, boundary-layer mixing, boundary-layer clouds, sub-grid orography, and surface heterogeneity.

The Division has devised and tested a one-dimensional stand-alone soil–canopy model. The model incorporates many of the important elements controlling local climate. These elements include soil type, surface albedo and roughness, exchange of water vapour by plants, deep soil percolation, and snow accumulation and melting.

The model's performance has been tested by comparing its output with observations from continental regions around the world and with the output from more detailed mesoscale models.

Dr Humio Mitsudera is studying ocean currents using a rotating tank. Water flowing into the tank models the wind-driven currents flowing through Bass Strait into the Tasman Sea.

General circulation model simulations incorporating elements of the soil–canopy scheme have been completed. This has enabled the geographical distribution of vegetation, surface albedo and aerodynamic roughness over land surfaces — using a data set from the US National Aeronautics and Space Administration (NASA) — to be incorporated realistically for the first time in our models.

The extensive simulations have yielded information on the sensitivity of regional climate to the model changes as well as highlighting weaknesses. Using information from overseas general circulation model simulations, the study has emphasised the tendency for surface net radiaton over continents to be over-estimated in numerical models.

Fluid transport

The oceans act as enormous storage reservoirs for heat. Large-scale ocean currents are important components of the climate system, transporting vast amounts of heat away from equatorial regions towards the poles. Yet the dynamics of these currents are still poorly understood.

The location at which currents move away from coastal areas may vary, influencing local rainfall. Increasing global temperatures due to the enhanced greenhouse effect may affect current behaviour.

The Bass Strait overflow occurs at the eastern edge of the continental shelf, where water depth increases rapidly. In winter, atmospheric cold fronts push Bass Strait water eastward. The cold, salty water leaving the Strait sinks, dropping to a depth of about 400 metres. This giant underwater waterfall has a major impact on regional current patterns.

The Shell Company of Australia is funding a laboratory tank investigation of the overflow. A model of the eastern part of Bass Strait is immersed in density-stratified fluid which simulates vertical variations in the ocean's density. The tank rotates, mimicking the rotation of the earth. Dyed salty water is introduced, allowing the passage of the outflow to be followed.

Bushfire meteorology

The impact of climate change on fire-danger indices throughout Australia is being examined in a collaborative project between the Division, the Division of Forestry and Monash University. The index is likely to rise in central, western and south-eastern Australia, but to fall, or remain unchanged, in the rest of the country.

This study confirms that long-term forest fire danger is strongly linked to relative humidity. Thus, fire danger is likely to increase in response to any decline in average relative humidity.

GLOBAL ATMOSPHERIC CHANGE

Vision

To provide world-class studies of the changing composition of the earth's atmosphere, the causes and effects of these changes and the efficiency and compliance of any Australian and international activities to minimize these changes.

Objectives

- To quantify and understand the mechanisms regulating climatically-active and ozone-depleting gases and aerosol in the regional and global atmosphere.
- Develop information on future atmospheric composition, and the effectiveness of proposed regulatory actions, particularly where these changes may affect the Australian community.

Introduction

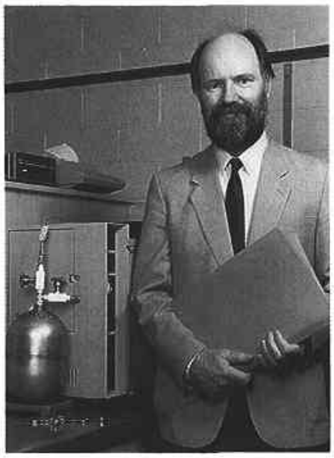
There is now strong evidence that the enhanced greenhouse effect will significantly modify regional and global climate early next century. Some changes may be beneficial, others may not.

Greatest benefits, and least dislocation to the Australian community, will be achieved by having available reliable predictions of the likely changes.

We need to understand why atmospheric composition is changing, how it will change in future, and how the climate system will respond to these changes.

This Program involves observations, numerical modelling and theoretical studies. These activities are improving our understanding of sources, sinks, exchange mechanisms and transformations of climatically-important gases and aerosol. Also of interest are gases which deplete stratospheric ozone.

Information comes from global sampling of the atmosphere, analysis of ancient air trapped in Antarctic ice, and studies of trace-gas emissions and aerosol production over Australia, the Southern Ocean and South-East Asia.



Mr Ian Galbally, Program Leader

GASLAB

The Division's Global Atmospheric Sampling Laboratory (GASLAB) has been operating since the end of 1990.

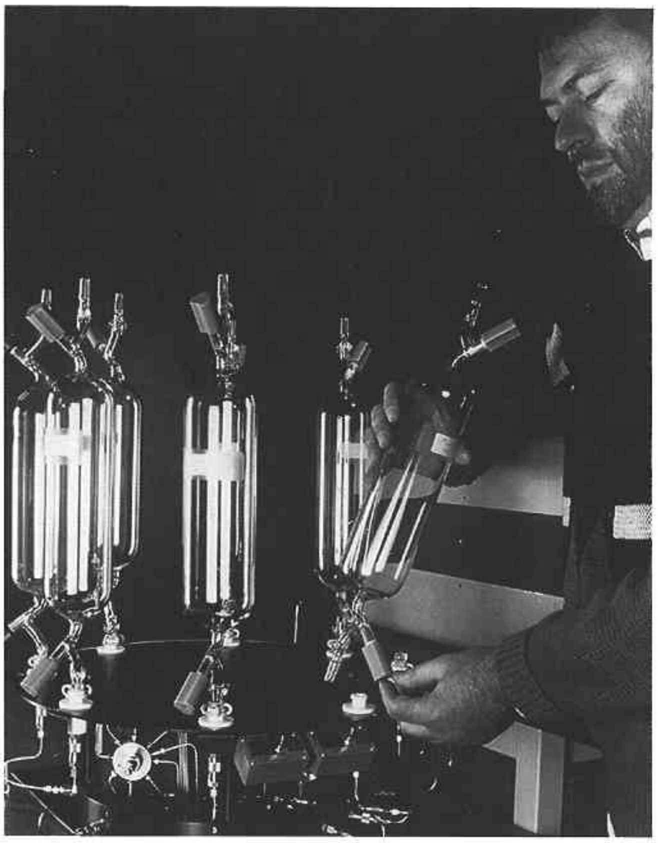
In GASLAB, precise measurements are made of the major greenhouse and ozone-depleting gases in air samples collected from around the world.

Measurement sequences are controlled by a centralised computer that processes and archives data, and provides comprehensive quality control and analysis.

Measurements are made of both trace-gas concentrations, using an array of gas chromatographs, and trace gas isotopic composition, using sophisticated mass spectrometer systems. For both atmospheric carbon dioxide and methane, stable carbon isotope measurements help distinguish between biological sources and physical and chemical sources of the gases.

Air samples collected from around the world are analysed within GASLAB. In addition, continuous, high-precision monitoring is conducted at the Cape Grim Baseline Air Pollution Station in Tasmania. There is extensive collaboration between GASLAB and Cape Grim in sample collection, instrumentation, calibration and data analysis. The Station, run jointly by the Bureau of Meteorology and CSIRO, is one of the foremost stations of the World Meteorological Organization (WMO) Global Atmosphere Watch program set up to monitor the chemical composition of the atmosphere.

Significant funding for GASLAB comes from the Department of the Arts, Sport, the Environment and Territories. Logistic support from collaborating institutions in Australia and around the world is an essential component of the GASLAB operation.



Dr Paul Steele prepares air flasks for chromatographic analysis in GASLAB.

ICELAB

Associated with GASLAB is the Ice Core Extraction Laboratory (ICELAB). Here, analysis takes place of tiny bubbles of air trapped in Antarctic ice cores drilled by the Australian Antarctic Division.

Ice cores from Law Dome, 100 kilometres from Australia's Casey Station, are currently being examined. Law Dome is an ideal site for core collection. The simple flow pattern and high snowfall means that annual ice layers can be accurately dated over the holocene (last 10 000 years). The most recently trapped air, from the 1970s, is of a similar age to the Division's archived air samples, thus allowing direct comparisons to be made.

The Law Dome core has shown the way in which atmospheric methane concentrations have varied in the past. Levels rose almost continuously from the 1840s to the 1970s. The only exception to the rapid growth during that period occurred from 1920 to 1945, when growth rate stabilised. The most likely explanation for the observed stabilisation is reduced global methane emissions, linked to the downturn in fossil fuel production during the two World Wars and the Great Depression of the 1930s.

Methane

Atmospheric methane concentrations have risen from about 750 parts per billion by volume (ppbv) prior to the industrial revolution to a current global average of 1700 ppbv.

However, latest measurements are showing that, while methane is still accumulating in the atmosphere, the growth rate is now declining. This finding is based on analysis of air collected from a United States global network of flask sampling sites. The network was originally established and operated by scientists who now work for the Division.

In 1983, the methane growth rate was about 13.3 ppbv a year. By 1990 it had fallen to about 9.5 ppbv a year. If the decline in growth rate continues unabated, atmospheric methane concentration is likely to peak by the year 2006, after which it will begin to drop.

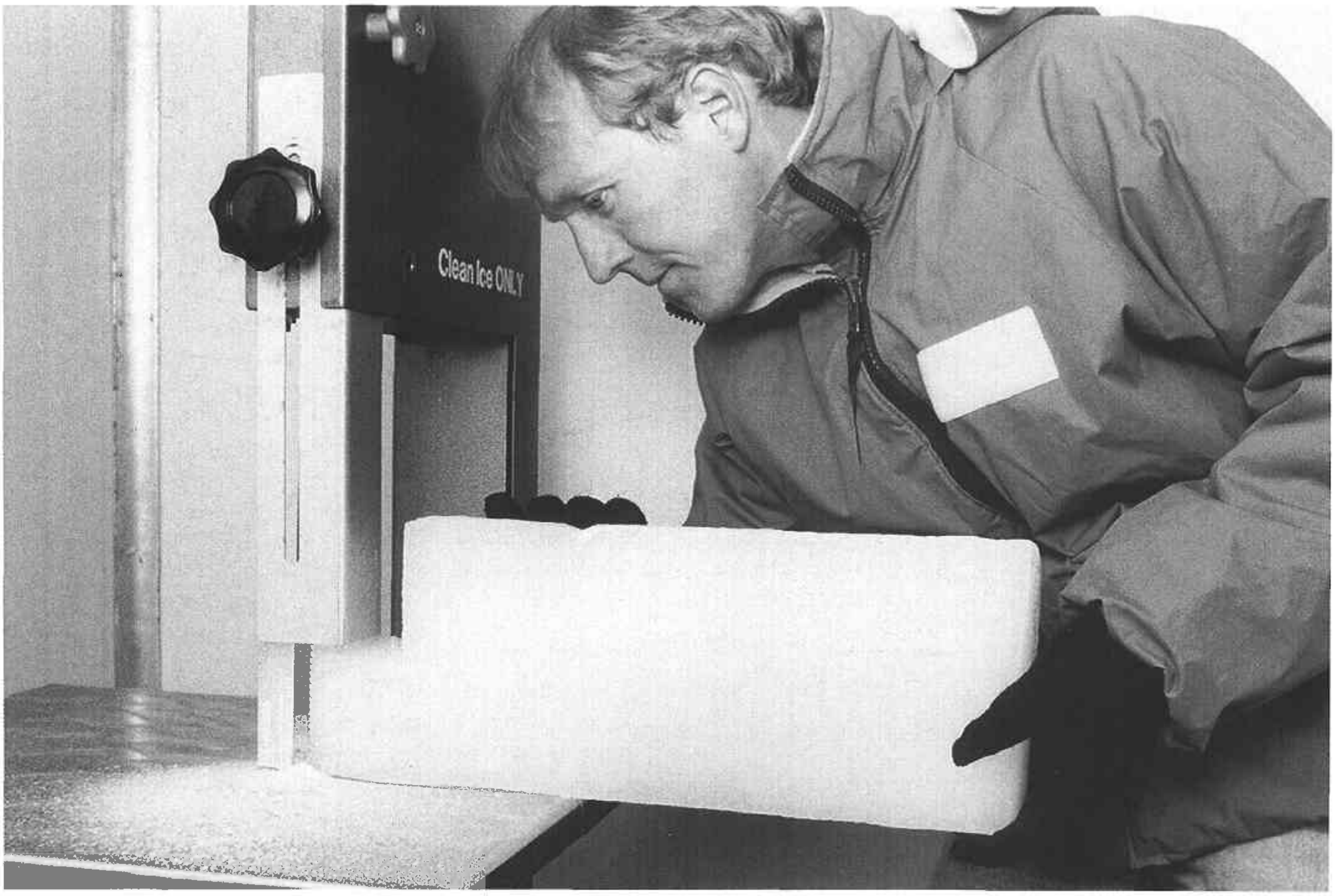
The reasons for the change are not clear, although it is in the northern hemisphere that the rate is dropping most dramatically. About 30% of atmospheric methane is released from land fills, coal mines and natural gas extraction. One possible explanation for the slow-down in accumulation is that there has been an increased effort to trap and burn methane for energy rather than allowing it to escape into the atmosphere.

Another possible explanation is that concentrations of the hydroxyl radical, the main sink for methane, are increasing. High hydroxyl radical concentrations are usually associated with increased urbanisation and industrial activity.

Tropospheric ozone

Ozone in the stratosphere is essential for life, protecting us from harmful ultraviolet radiation. In the troposphere, however, ozone is a pollutant associated with photochemical smog. It is also a greenhouse gas.

Until the 1970s, it was assumed that, except near urban areas during high pollution, tropospheric ozone was chemically inert and originated from the stratosphere. However, this hypothesis did not satisfactorily explain differences in tropospheric ozone concentrations between the northern and the southern hemisphere.



David Etheridge slices a section of Antarctic ice core, provided by the Australian Antarctic Division, in ICELAB prior to extraction of air for analysis.

It became clear that photochemical reactions may be producing and destroying ozone in the non-urban troposphere. Until recently, there has been little experimental evidence to support this theory.

Ozone and hydrogen peroxide concentrations have now been continuously monitored at Cape Grim for a year. Hydrogen peroxide is of interest because it is produced during the photochemical breakdown of ozone.

Maximum ozone concentrations occurred in winter when levels of hydrogen peroxide were low. In summer, ozone concentrations were at a minimum, coinciding with peak peroxide concentrations. The numerical model used for this study accurately simulated the observed concentration changes.

This is the first conclusive evidence that photochemistry dominates the ozone budget in much of the troposphere.

Chlorofluorocarbons and methyl chloroform

The Montreal Protocol, an international treaty limiting the production of ozone-depleting substances, such as chlorofluorocarbons (CFCs) and methyl chloroform, appears to be working.

Measurements taken at Cape Grim show that increases in the tropospheric concentration of CFC-11, CFC-12 and methyl chloroform are slowing. The rate of increase of CFCs and methyl chloroform have declined from about 5% a year during most of the 1980s to about 3% since 1988.

The methyl chloroform data suggest that the tropical tropospheric abundance of hydroxyl radical — the major sink for methyl chloroform and methane — is increasing by about 1% per year. (This increase in hydroxyl concentration would make a significant contribution to the observed decline in methane growth rate.)

Despite the slowdown in the rate of increase of a number of ozone-depleting chemicals, satellite data show a statistically significant loss of stratospheric ozone over southern Australia. Stratospheric ozone losses over Sydney, for example, during the 1980s corresponded to an increase in UV-B radiation at ground level of about 6%.

The Division calculates that the Montreal Protocol (as amended in 1990) is likely to result in stratospheric chlorine concentrations peaking at 4.1 ppbv in the year 2000, not returning to 1987 levels of 2 ppbv until 2060. The Protocol is due to be revised again in November 1992.

Sources of greenhouse gases

Carbon cycle modelling

A range of theoretical studies are being undertaken to improve our understanding of the global carbon cycle. The Division's carbon cycle modelling activities place particular emphasis on quantifying the uncertainties in model-based estimates. A new formalism has been developed for combining the estimates and uncertainties from the many disparate types of information about the carbon cycle.

A box-diffusion model of the ocean, coupled to lumped representations of the atmosphere and terrestrial biota, is employed for long time-scale studies. It has been used to calculate projected carbon dioxide concentrations for the next century, as part of the studies for the 1990 Intergovernmental Panel on Climate Change (IPCC) Report. The model has also been used to predict that adopting the 'Toronto target' of reducing carbon dioxide emissions to 80% of 1988 levels by the year 2005, will lead to carbon dioxide concentrations of around 470 ppm in the year 2100 compared to 830 ppm resulting from the IPCC 'Business-as-Usual' scenario.

Two-dimensional models are used to deduce the latitudinal variations of sources and sinks of carbon dioxide from the spatial distribution of carbon dioxide concentrations. New techniques have been developed to quantify the uncertainties in these 'inverse calculations'.

In mid-1991, a new three-dimensional transport modelling program was established with the support of the State Electricity Commission of Victoria. Three-dimensional modelling makes it possible to explore the longitudinal variability in greenhouse gas distributions. It also provides the capability of resolving the synoptic-scale variability, or 'chemical weather', associated with transport variability that is averaged-out in two-dimensional models.

Emissions from soil

Agricultural practices change the way in which soils release and take up gases. To better understand the impact of agriculture on greenhouse gas emissions from soils, a field experiment has been undertaken in north-western Victoria.

Two sites with similar soil types were selected. At one site the land was in a natural, untouched state, covered with eucalypts and spinifex. The second site, a few kilometres away, had been intensively farmed for 60 years.

Measurements were made in autumn and then repeated in winter, spring and summer.

Gas fluxes were measured by placing a specially-constructed transparent chamber over a small area of soil. Changes in concentrations within the chamber of carbon dioxide, nitrous oxide, methane, carbon monoxide and oxides of nitrogen were monitored.

In autumn and winter, soil respiration rates were higher at the natural site than at the farm. However, seasonal changes were far greater than any differences between locations.

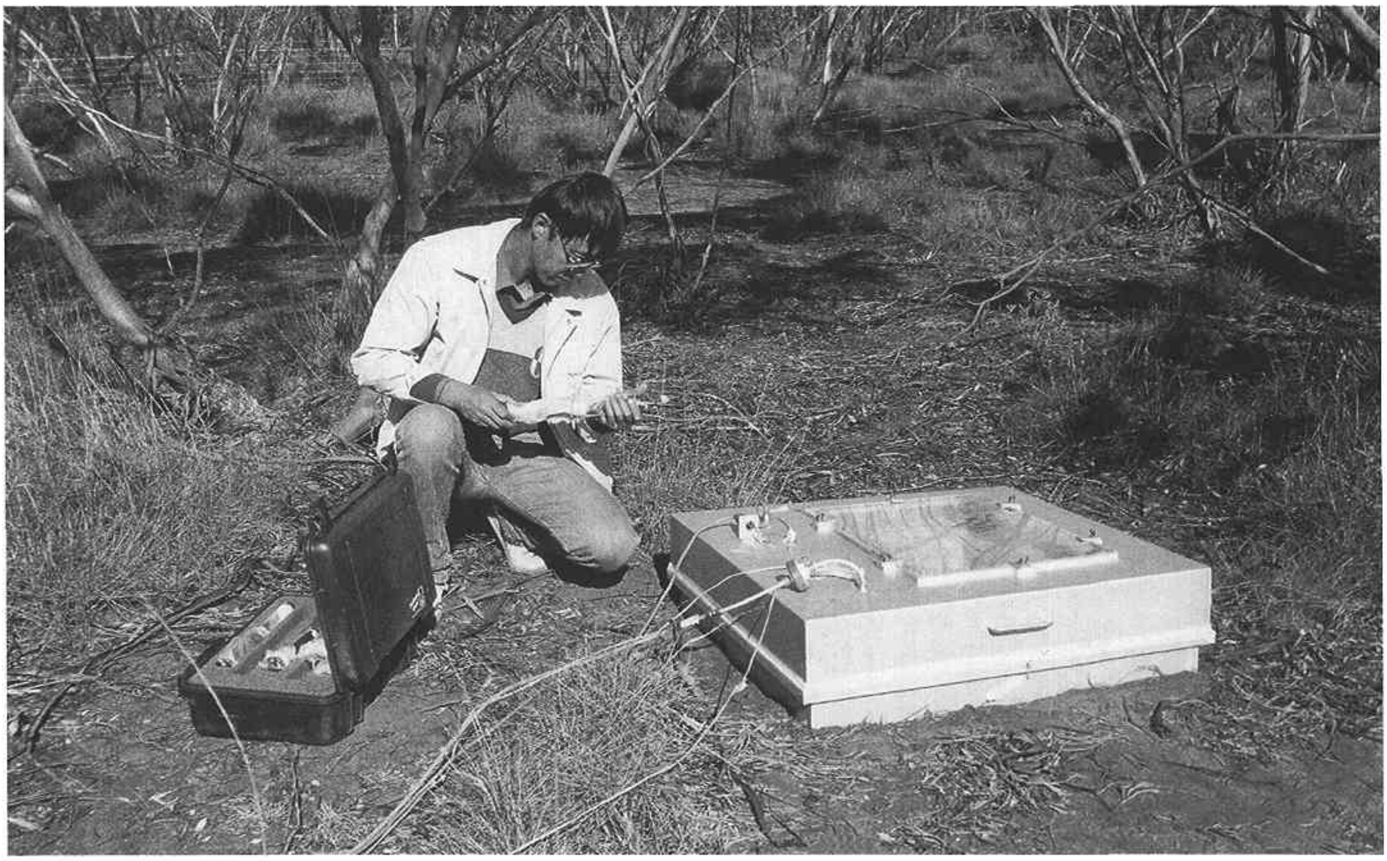
Methane is absorbed by soil and then oxidised. The amount of methane consumed by natural processes in Australian soils was found to be considerable. In fact, it is equivalent to all the methane produced by livestock in this country.

Nitrous oxide, on the other hand, is emitted from soil. Emission rates were low. However, the area of semi-arid land on earth is large, and this work suggests that these regions are a major global source of the gas.

As well as providing information about the way in which agricultural activities affect gas emissions, data collected will also tell us about seasonal variations of gas fluxes from Australia's arid regions. Ultimately, the experiment will improve estimates of our annual production of greenhouse gases.

Following this study, the Division organised a workshop designed to gather current knowledge and to recommend priorities for future research and monitoring. The Workshop on Agriculture and Greenhouse in South-Eastern Australia attracted more than 40 scientists, agricultural extension officers and policy-makers from Australia and New Zealand.

This project has been funded by the Victorian Office of the Environment and the Commonwealth



Professor Shang Shuhui, a visitor to the Division from the Institute of Applied Ecology in China, monitors the release of greenhouse gases from soil at a site in northern Victoria.

Department of the Arts, Sport, the Environment and Territories, and has been supported by the Victorian Department of Food and Agriculture.

Urban emissions

In cooperation with the Environment Protection Authority of Victoria, the Division has completed a preliminary study of methane and nitrous oxide release from motor vehicles.

Air samples were collected in Melbourne's central business district during the morning peak hour and subsequently analysed by gas chromatography.

Methane was estimated to make up about 16% of the hydrocarbons present in the air samples. Based on this study, Australian motor vehicles release 92 000 tonnes of methane and 5 000 tonnes of nitrous oxide each year.

Aerosol

Air at its cleanest may contain between 10 and 100 tiny liquid and solid aerosol particles in every cubic centimetre. Heavily polluted air may have up to 100 000 particles per cubic centimetre.

Aerosol particles influence the amount of solar radiation reaching the earth's surface as well as how much infrared radiation from the surface disappears into space.

The particles also act as cloud condensation nuclei, playing a major role in determining the amount and type of clouds. Without clouds, average surface temperature would rise from about 15°C to about 30°C. Global warming is likely to be accelerated if high altitude clouds become more prevalent in future. This is an example of a positive feedback on world temperatures.

While fossil fuel burning is increasing the amount of carbon dioxide in the atmosphere, it is also adding to the amount of sulfate aerosol particles in the atmosphere. By reflecting more solar energy, these particles could be limiting the amount of warming observed, especially in the northern hemisphere, where most the world's fossil fuels are being consumed.

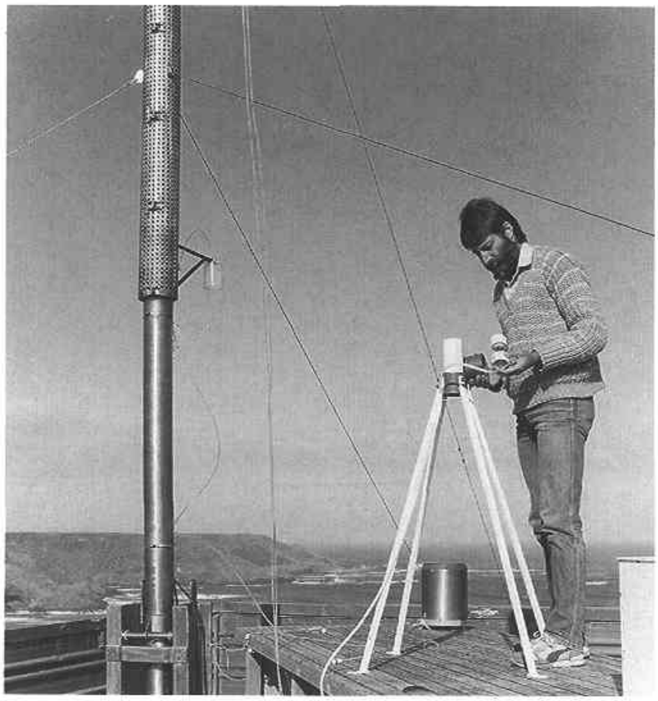
The second greatest source of sulfur-based aerosol particles is a natural one — marine plankton. Some planktonic marine algae produce dimethyl sulfide

(DMS) as they metabolize. One estimate has suggested that these plants produce more sulfur each year than the total sulfur output from the world's volcanoes. Once released into the atmosphere, DMS is quickly oxidised to sulfur-containing aerosol particles which act as cloud condensation nuclei.

This relationship between DMS emissions and cloud condensation nuclei may provide another climate feedback mechanism — one that may help minimize global warming. The suggestion is that as world temperature increases, plankton metabolize at a greater rate, producing more DMS. The number of sulfur particles increases, clouds become brighter and more reflective and have more of a cooling effect.

To test the hypothesis, information is needed about the relationship between cloud condensation nuclei numbers and the concentration of sulfur-containing aerosol particles in clean marine air. There is only one place in the world where these data exist — for the last ten years measurements have been made at Cape Grim.

The measurements show a strong link between atmospheric DMS and sulfate aerosol particles, adding weight to the theory that marine plankton play an important role in regulating climate.



Dr Greg Ayers inspects an aerosol collector on the observation deck at the Cape Grim Baseline Station.

RADIATION AND CLIMATE

Vision

A Program to undertake quality research into the interaction of solar and infrared radiation with the atmosphere and surface, interactions which ultimately determine our present climate and environment, to respond to Australian community needs in remote sensing and to collaborate with Australian and international agencies with similar interests.

Objectives

- Reduce the present uncertainties in predictions of climate and climate change due to radiative cloud and surface feedback processes, using satellite and surface remote sensing methods and theoretical models.

- Use and interpret satellite data sets, develop aerospace instrumentation where appropriate, and apply our improved knowledge to user needs in the Australian community.

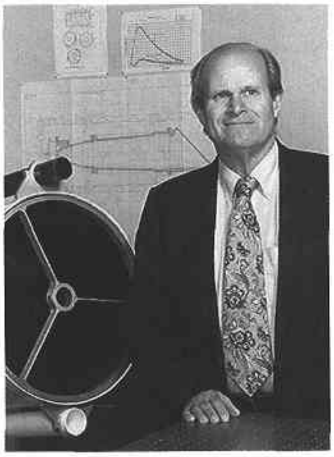
Introduction

Our environment and climate are determined by the interaction of solar and infrared radiation with the earth's surface and atmosphere. It is this interaction that is the focus for the Program.

Clouds have a major influence on the earth's energy balance. It is clear that clouds are likely to have a feedback effect on global warming. What is unclear, however, is the likely nature of this feedback. The Intergovernmental Panel on Climate Change (IPCC) has recognized this uncertainty, calling for a better understanding of radiative and structural properties of clouds. This will lead to improvements in the way clouds are represented in climate models.

Better measurements of land- and sea-surface temperatures are needed for climate models. Data from National Oceanic and Atmospheric Administration (NOAA) satellites and from the Along Track Scanning Radiometer (ATSR) on board the ERS-1 satellite are improving the accuracy of such measurements.

The Program has made a major contribution to the development of remote sensing instruments. Instruments currently being developed include an



Dr Martin Platt, Program Leader

atmospheric pressure sensor, an aircraft-mounted instrument for the detection of volcanic ash clouds, and a three-wavelength scanning lidar for ground-based atmospheric monitoring.

Atmospheric processes

Clouds and radiation

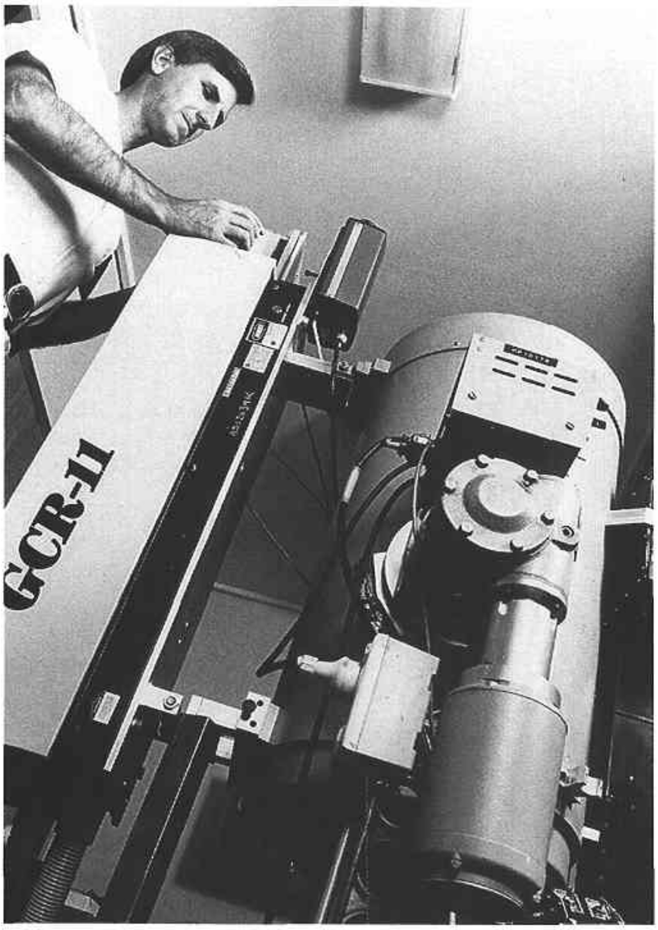
The second observational phase of the Experimental Cloud Lidar Pilot Study (ECLIPS) took place in mid-1991. ECLIPS, which involves scientists from around the world, is directed from the Division. The study is designed to obtain information on cloud structure and the interaction of clouds with radiation.

Ground-based lidars (laser radars) provide information, often inaccessible to satellite instruments, on cloud-base height and cloud extinction (light absorption).

An interesting phenomenon detected by lidar measurements at Aspendale was the nucleation and growth of cloud droplets as they ascended within stratocumulus clouds. Extinction profiles compare well with theoretically determined growth curves.

At times, measured extinction values were less than predicted. This is likely to be due to entrainment of dry air into cloud tops due to radiative cooling. Lidar readings indicate, not only the mean extinction, but a measure of the variability and, thus, the turbulent processes involved.

In heavily populated and industrialised regions, clouds contain high concentrations of condensation nuclei. This increases extinction, reflecting more solar radiation back into space, acting as a negative feedback to global warming. Lidar observations of clouds in the northern hemisphere will provide an interesting comparison with observations made here.



Dr Stuart Young checks the focusing mechanism of the Divisional lidar. The lidar sends powerful laser pulses into the atmosphere. Airborne particles reflect the laser beam back into an optical telescope connected to a processing system. The time taken for the pulse to be reflected gives the height of the particles, while the strength of the signal indicates the amount of material present.

ECLIPS measurements will be made next year at the Cape Grim Baseline Air Pollution Station and in New Guinea. The New Guinea measurements are to be part of the Tropical Oceans and Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA COARE).

The Division is currently constructing a sophisticated new lidar. The new instrument features a high repetition rate laser, allowing rapid scanning of the boundary-layer, and can operate at three wavelengths. These features give the lidar great versatility.

The United States Department of Energy is funding the construction of a new infrared radiometer. The instrument will be used for cloud studies at sites in Northern America and the western Pacific.

Regional cloud climatologies

Locally available, high-resolution NOAA and Geostationary Meteorological Satellite (GMS) data are being used to investigate cloud cover over the Australian region. Diurnal and seasonal distribution will be described in a project designed to provide information for international studies as well as regional modelling studies. To date, few comparisons with observations have been made of model-generated cloudiness, so the data will be important both for validating regional studies and for providing baseline measurements to assess climate change.

This work has a number of direct research applications. Of particular interest will be information about the relationship between aerosol concentrations over the ocean and cloudiness. Cloud statistics can also show the amount of light available to plants for photosynthesis, valuable information for biological studies.

Measuring surface pressure from space

Weather forecasting, especially for the Australian region, would benefit significantly if it were possible to measure accurately atmospheric surface pressure from space.

A prototype of an atmospheric pressure sensor, designed to be mounted on a satellite, has been developed at the Division. The sensor consists of a high resolution spectrograph tuned to a wavelength at which oxygen is the only absorbing molecule. Light reflected from the ocean's surface up to the sensor will be analysed. Since oxygen is well-mixed in the atmosphere, the absorption by this gas indicates the mass of air present above the ocean surface and, hence, the atmospheric pressure.

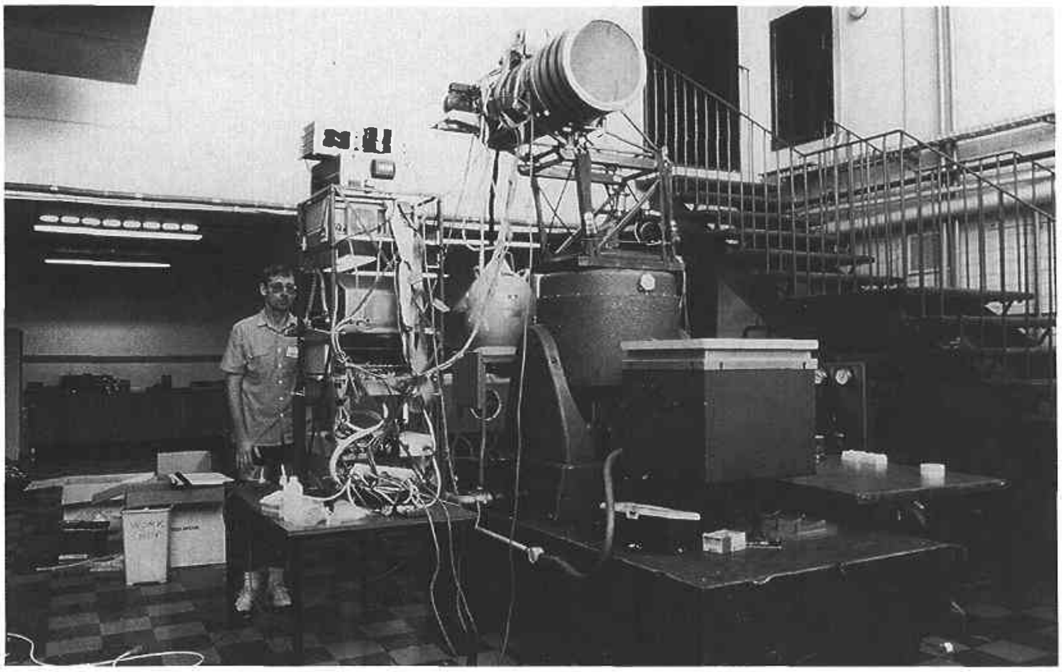
Optical, thermal and mechanical properties of the instrument are being examined and extensive modelling and instrumental analysis is underway.

The Australian Space Office is supporting the project. VIPAC Engineers and Scientists Ltd has appointed two staff members to work at the Division.

Volcanic ash over Australia

The eruption in June 1991 of Mount Pinatubo in the Philippines blasted millions of tonnes of sulfur dioxide and ash high into the atmosphere.

The first recording of aerosol from Mount Pinatubo over Australia was made at the Division. On 19 July, lidar soundings at Aspendale showed the presence of an offshoot of the main ash cloud at a height of



Dr Denis O'Brien subjects the atmospheric pressure sensor to vibration testing in preparation for mounting the instrument in an aircraft. This testing is being done at the laboratories of VIPAC Engineers and Scientists Ltd in Melbourne.

22 kilometres. That evening, and in the weeks and months following, spectacular sunsets were seen in many parts of Australia.

According to NASA, the Mount Pinatubo eruption increased the amount of silicate dust and aerosol in the stratosphere by 60 to 80 times. Once in the stratosphere, sulfur dioxide is oxidized, forming tiny aerosol droplets of sulfuric acid. These droplets are very efficient at scattering solar radiation back into space. While ash falls out of the atmosphere within months, the sulfuric acid droplets are likely to remain for up to three years.

Almost a year after the eruption of Pinatubo, the particles it released are still densely distributed throughout the atmosphere, ranging in height from 15 to 30 kilometres, with a peak concentration at approximately 18 kilometres. Horizontally, the greatest concentration is near the equator, but material has been measured at high latitudes in both hemispheres.

As well as possibly temporarily off-setting the recently recorded rise in the earth's surface temperature, the volcanic aerosol may act like polar stratospheric clouds, accelerating ozone depleting reactions.

Surface processes

Measuring sea-surface temperatures

The Along Track Scanning Radiometer, first proposed as a satellite instrument by the Division over ten years ago, was launched from French Guiana on board the ERS-1 satellite in July 1991.

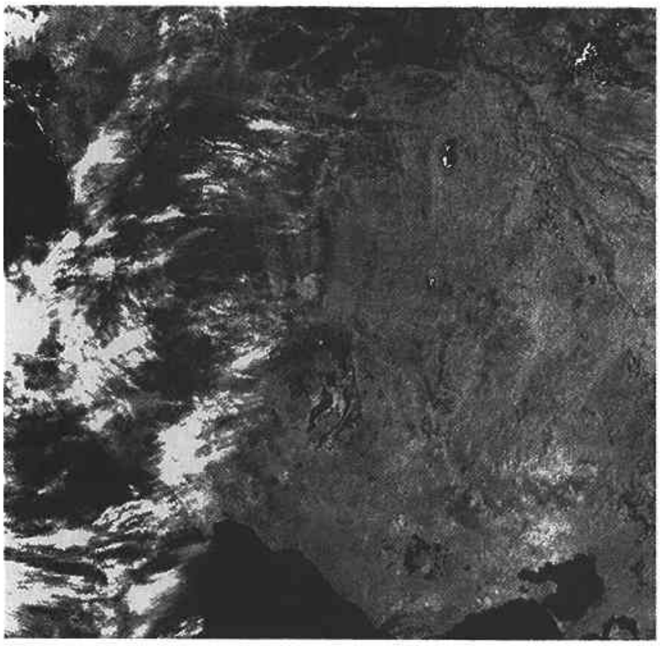
The radiometer was built by a consortium of institutes in the United Kingdom, France and Australia. It is designed to provide accurate measurements of sea-surface temperatures. This will be of great use for forecasting climate variations and in assessing climate change.

A feature of the instrument is its dual view of the earth's surface. The forward scan in addition to the normal downward looking scan, when matched for the same location, allows corrections to be made for the intervening atmosphere.

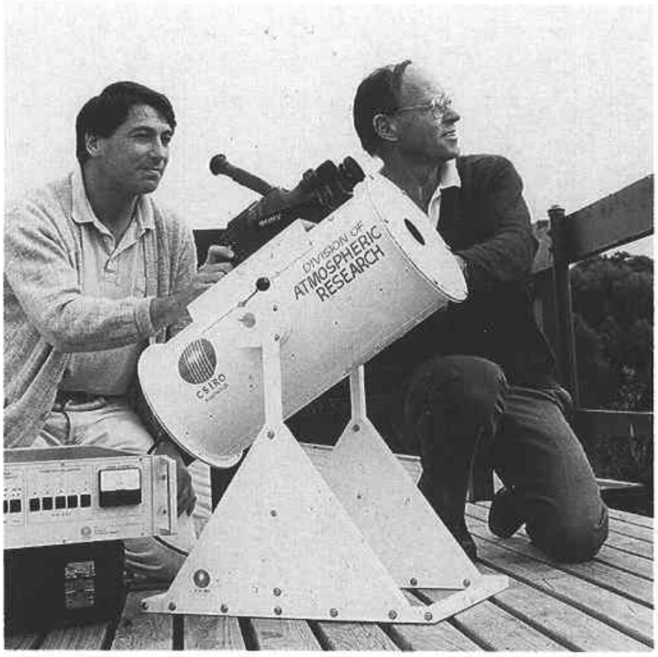
Several research vessel cruises have been undertaken in the Coral Sea to compare ground-based measurements with those from the ATSR. Results from these validations show that the instrument is performing as expected — sea-surface temperature measurements are accurate to within 0.25°C.

The ATSR project is led by the Rutherford Appleton Laboratory in the United Kingdom. Support for Australian involvement has come from the Department of Industry, Technology and Commerce.

Plans for the ERS-2 satellite are well underway. The satellite, which is to be launched in 1994, will also carry an ATSR. The Division will be the Australian leader of the scientific program to validate and use sea-surface temperature and other measurements made by the radiometer.



An infrared image of southern Australia produced by the Along Track Scanning Radiometer on board the ERS-1 satellite. Cloud cover, lakes and major rivers are clearly visible.



Dr Fred Prata and Dr Ian Barton with a prototype of their Airborne Hazard Detection System, which has been designed to give airline pilots advanced warning of volcanic ash in their flight path.

Measuring land-surface temperatures

Accurate measurement of land-surface temperature from space is important for weather forecasting and other applications. Temperature measurements are also critical to our understanding of air-land energy and moisture exchanges.

However, measuring land surface temperature from satellite instruments is difficult. Variations in atmospheric water vapour and surface emissivity introduce uncertainties. Errors in temperature measurements of complex land forms can be up to 3°C.

The Division is improving the accuracy of remotely sensed land surface temperatures. In conjunction with a related field experiment on frost risk, extensive temperature measurements have been made in a wheat field in north-western Victoria. These measurements were regularly compared with those derived from satellite-mounted instruments. This has enabled the development of new land-surface temperature algorithms that include both atmospheric and emissivity corrections.

To investigate different surface types, a similar study at two new sites, one in New South Wales and one in Queensland, will begin soon.

The frost risk project has now been completed and seasonal maps of frost occurrence have been produced. The project has shown that temperature variations across growing regions can be mapped successfully using satellite technology. These maps can improve the efficiency of farming operations. For example, sowing times and alternative crops can be chosen to reduce the impact of frost. An extension booklet for farmers on frost incidence and its regional variations is being produced by the Division with the Victorian Dry Land Farming Institute in Horsham.

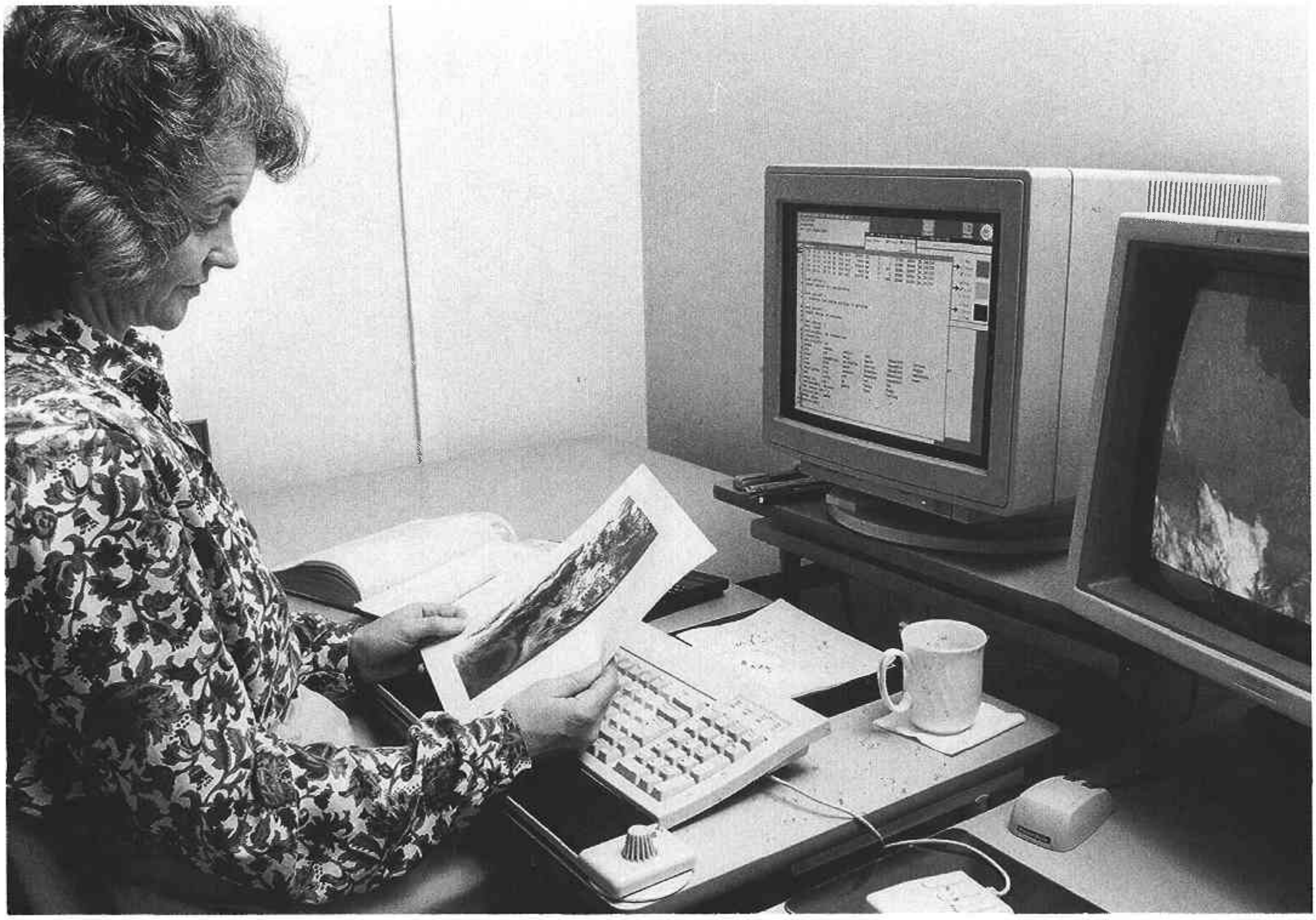
Further details of the frost risk project appear in the Division's 1988–1990 Research Report.

Improving aviation safety

An instrument has been developed to warn pilots of volcanic ash clouds. Volcanic ash can be hazardous to planes, as the tiny particles of silica may melt when drawn into a jet engine, preventing air flow and causing the engines to stall.

The Division's Airborne Hazard Detection System is a multi-channel infra-red radiometer, able to distinguish between volcanic clouds and normal water and ice clouds at distances of up to 100 kilometres. This is achieved by measuring the clouds' thermal radiation at 11 and 12 micrometre wavelengths, where volcanic clouds differ most from water clouds.

Successful testing of the instrument has been done on the slopes of Mount Sakurajima, an active volcano in southern Japan. The tests, conducted in cooperation with Kyoto University, confirmed theoretical and modelling studies.



Using sophisticated software, the Division's CSIDA facility collects and processes data from up to six satellite overpasses each day. Here, Janice Bathols checks details of cloud coverage on a satellite image of southern Australia.

CSIDA

The CSIRO System for Interactive Data Analysis (CSIDA) regularly collects high-resolution picture transmission data from NOAA polar-orbiting meteorological satellites.

CSIDA provides data for scientific activities within the Division, and produces a variety of value-added products. These include bushfire risk maps, images for television weather services, frost risk maps, and sea-surface temperature charts for the fishing industry.

WATER RESOURCES AND CLIMATE CHANGE

Vision

A Program providing a world-class climatic modelling facility that is capable of addressing currently perceived, as well as developing, environmental issues of regional and global concern both as a domestic and international consultant.

Objectives

- To develop systematically the individual components of a climatic modelling facility and to apply them separately or collectively to critical environmental problems.
- To convert current qualitative understanding to quantitative outcomes so that sound decisions can be made in such areas as greenhouse impacts or drought prediction.
- To use results in appropriate consulting studies both nationally and internationally.

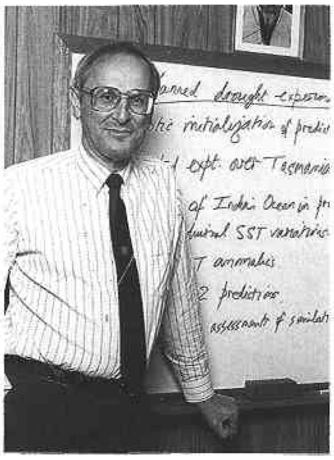
Introduction

The driving force determining our climate is heating by incoming short-wave radiation from the sun and cooling by long-wave radiation into space. The world's climate depends on complex interactions between the atmosphere, the oceans and other components of the climate system.

General circulation models provide a powerful tool for studying climate and climate change. The Division has developed a range of world-class general circulation models and limited-area models. Results from these models are being applied to critical environmental issues.

The Program has three research streams: climate change research, drought prediction, and precipitation studies.

Climate change research is producing scenarios and assessments of the likely nature of climate change resulting from the enhanced greenhouse effect. This work relies on increasingly complex and more realistic general circulation models. Limited-area models in both stand-alone and nested modes also provide important information, permitting finer details to be studied. The likely impacts of climate change are currently being assessed for Australian States and Territories and for international authorities.



Mr Barrie Hunt, Program Leader

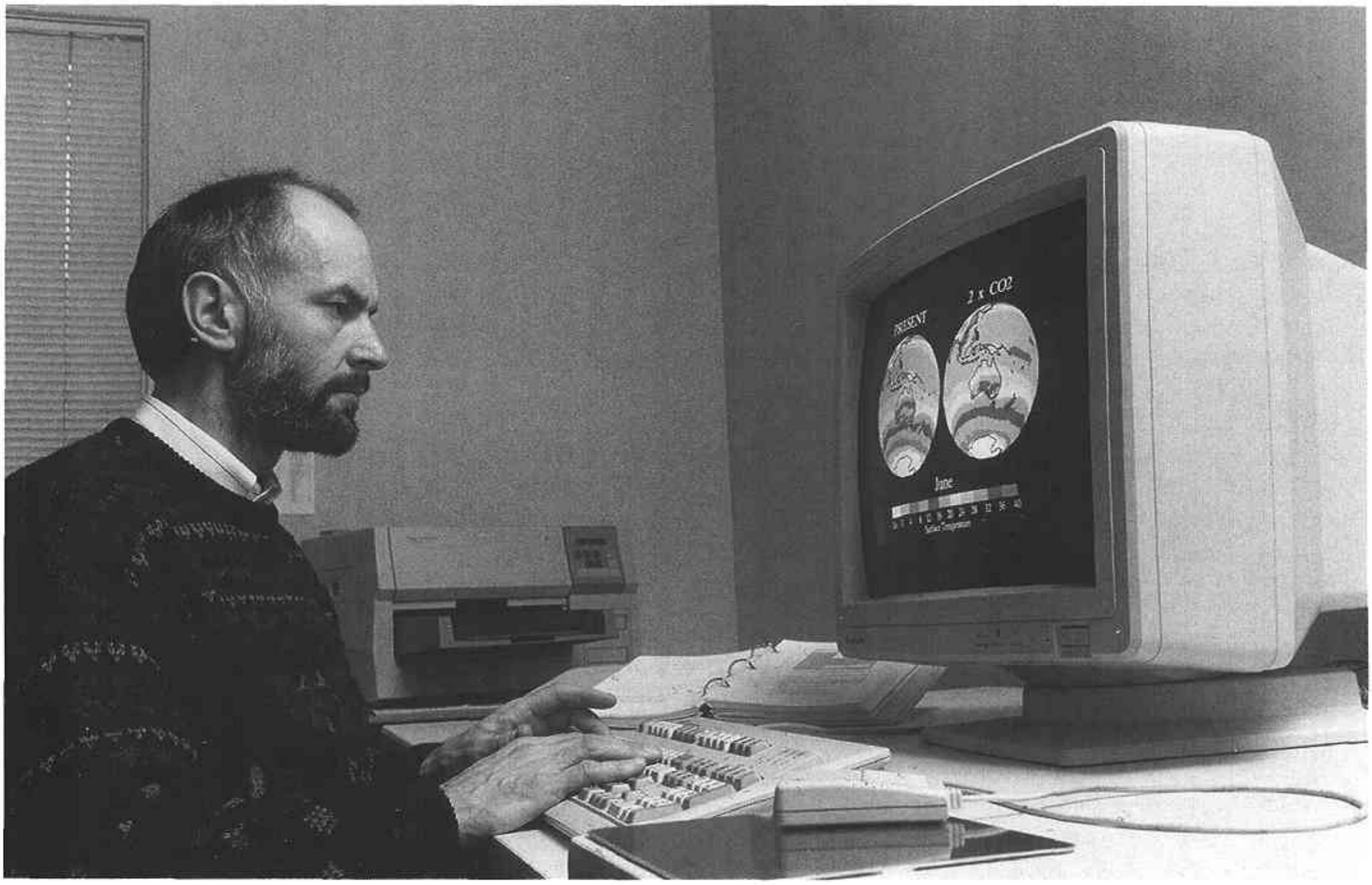
Drought studies within the Division rely on model simulations and predictions of seasonal and interannual variability, particularly of rainfall. Past and forecast records of sea-surface temperatures provide important data for these studies, which are aimed at developing a reliable drought prediction scheme.

Limited-area models are an excellent tool for investigating intense precipitation events, such as tropical cyclones and storm systems, and convective mechanisms. A major objective of the Division's precipitation research is to investigate the possibility of improving current estimates of probable maximum precipitation. In addition, an extensive precipitation enhancement study, including cloud seeding and innovative research, has been conducted in conjunction with Melbourne Water.

General circulation modelling

The development and application of general circulation models is of central importance to climate and climate change research in Australia. The models must be capable of considering all the atmospheric, terrestrial and oceanic processes that determine our climate.

Climate change investigations are carried out by first simulating present climate, using current atmospheric carbon dioxide concentrations. The simulation is then repeated using doubled, or gradually increasing, levels of carbon dioxide.



Dr Hal Gordon uses the CSIRO 9-level model to investigate the effect of a doubling of atmospheric carbon dioxide concentrations.

Intensive model development and testing continues. To better represent processes near the earth's surface and in the stratosphere, increased vertical resolution is needed. The dynamical framework of the CSIRO 4-level model served as a framework for the construction of a 9-level model. Using prescribed sea-surface temperatures, the model is now able to realistically simulate most of the important features of the atmospheric general circulation on a diurnally and seasonally varying basis.

The 9-level model has been used for a 40-year simulation of present climate. Using a slab ocean, excellent agreement was found with observed precipitation, mean sea-level pressure, surface temperature variations over Australia and jet-stream patterns.

A 60-year simulation with doubled carbon dioxide levels produces a mean annual surface warming near the upper range estimated by the IPCC, but comparable with results from other models using similar cloud parameterisation schemes.

Horizontal resolution in the 9-level model is a grid size equivalent to 350 × 610 kilometres. To improve results for regional simulations, horizontal resolution is to be doubled.

Coupling atmospheric and oceanic models

Oceans are an important part of our climate system, storing heat in summer, releasing it in winter, and transporting it towards the poles. Thus, to realistically simulate climate, atmospheric models must be coupled to oceanic models.

This coupling is important, as the rate of heat uptake by the deep oceans and any consequent change in deep ocean circulation may have a great bearing on the impacts of the enhanced greenhouse effect.

Oceans are also a major sink for carbon dioxide. Any changes to circulation patterns will affect the carbon cycle and, therefore, atmospheric concentrations of carbon dioxide.

The Division is developing 12- and 36-level ocean general circulation models with horizontal resolution equivalent to that of the CSIRO 4- and 9-level atmospheric models. The first coupled atmospheric–oceanic model runs have been completed. Preliminary carbon cycle experiments with the oceanic model are designed to assess the way in which oceans are likely to affect transient carbon dioxide concentrations in the atmosphere.

Warming due to the enhanced greenhouse effect is likely to be more pronounced near the poles than elsewhere. This is almost entirely due to changes in the albedo, or reflectivity, of polar regions. Warming leads to melting of snow and ice, decreasing the amount of solar radiation reflected back into space. Thus, further warming is expected — this is a positive feedback. In addition, warming reduces the thickness of floating ice, allowing a greater flux of heat from the ocean in winter, further enhancing surface warming. An improved model of sea-ice formation and decay has been developed and coupled to the CSIRO 9-level model.

Limited-area modelling

Global circulation models have a horizontal resolution of approximately 500 kilometres, whereas local precipitation and soil-moisture patterns are often related to small-scale features. The Great Dividing Range, which has a major impact on Australian climate, is not represented at all in 500-kilometre resolution models. Running a global model at higher horizontal resolution can be prohibitively expensive. An attractive alternative is to carry out a full global simulation and then nest a higher-resolution mesoscale model within it, so that the global model is supplying the broad climatology.

The Division's limited-area model has been nested within the CSIRO 9-level model, supplying a horizontal resolution of 250 and 125 kilometres. Experiments for enhanced greenhouse conditions involving detailed regional simulations should soon be possible.

The limited-area model has also been used for meteorological studies. Weather phenomena such as east-coast lows and tropical cyclones have been examined with a 75-kilometre horizontal resolution and 18 vertical levels.

Predicting drought

The Division's Centre for Drought Research is using atmospheric general circulation models to assess the spatial relationship between sea-surface temperature anomalies and drought in Australia. The influence of land-surface conditions and internal atmospheric variability are also being investigated.

Most large-scale, long lasting droughts in the eastern half of Australia are related to El Niño events. This is why simulating such events is a fundamental part of the drought program.

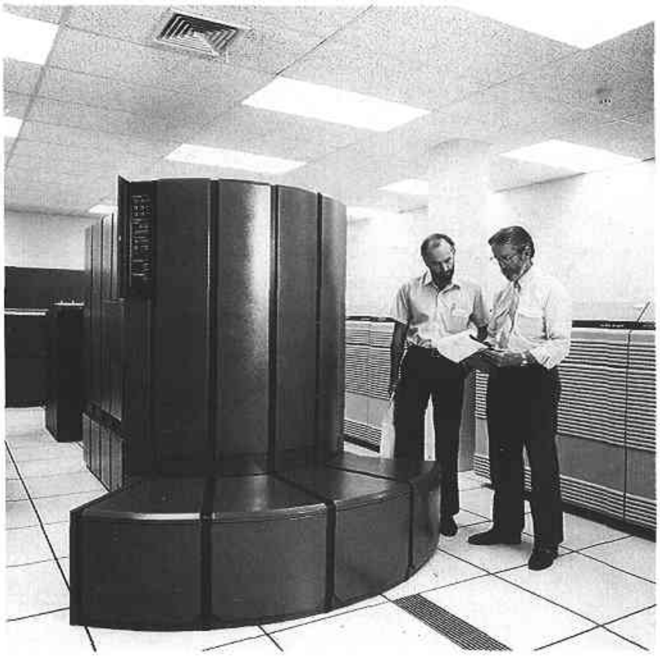
Experimental predictions of Australia's climate, particularly rainfall, for 12 months ahead have been made for 1991 and 1992 and will be continued for future years. Increasingly realistic simulations should lead to improved predictions.

The impact of climate change

The Division is using its expertise to suggest the way in which the enhanced greenhouse effect may alter our climate. The Climate Impact Group provides specific and regional scenarios of plausible changes in various parts of the country for use by groups who wish to assess sensitivity to climate change.

One likely change identified by the Group is an increase in the frequency of heavy rain events. The CSIRO 4-level and 9-level general circulation models both suggest that, in future, the time between heavy rainfalls may decrease significantly in Australia and many other parts of the world.

If such changes were to occur, the frequency of flooding would increase. This would have serious implications for the design of drains, dams and bridges.



Dr Barrie Pittock and Dr Hal Gordon discuss the results of general circulation models run on the CRAY Y-MP supercomputer. A high-speed link joins the Aspendale site to South Melbourne, where the supercomputer is housed.

The Division's Climate Impact Group believes that the enhanced greenhouse effect may lead to a general increase in rainfall intensity and a concomitant increase in the incidence of flooding.

The Group has produced annual reports for the Victorian, Northern Territory, Western Australian and New South Wales Governments.

As well as detailing possible rainfall changes, the annual reports contain extensive information about likely changes to temperature, sea level and other meteorological phenomena. The way these changes may affect agriculture, water supplies, snow fields, fire danger, floods, and temperature extremes is also examined in conjunction with experts in these fields.

Information from a variety of sources is used to prepare these reports, including results from local and overseas general circulation models, from limited-area models, and from the analyses of historical records and palaeoclimatic information.

The Climate Impact Group is funded partly by the Department of the Arts, Sport, the Environment, Tourism and Territories, and partly by the State and Territory governments listed above.

Cloud Processes

General circulation models and limited-area models do not have the resolution to explicitly treat convection and cloud–radiation processes. Instead, these processes must be parameterised. To improve the models, a better description must be found of shallow and deep convection, and the impact of clouds on radiation fluxes.

During field work, measurements have been made of the microphysical and radiative properties of both shallow and deep mixed-phase clouds. Mean particle size and distribution of liquid water and ice in clouds will be used to determine radiative properties.

Precipitation forecasting

Dam spillways must have sufficient capacity to safely carry away water during a sudden downpour over the catchment area. Water authorities rely on estimates of probable maximum precipitation for the design of spillways, which are expensive to build.

Probable maximum precipitation is an estimate of the highest rainfall event likely to occur over the catchment area. It is determined statistically from analysis of historical rainfall patterns.

Numerical modelling is being used to investigate the validity of probable maximum precipitation estimates. The model chosen for the exercise is Colorado State University's Regional Atmospheric Modelling System. Already, the model has satisfactorily simulated flow fields, cloud physics and precipitation observed during the Australian Winter Storms Experiment.

This five-year project is funded by the Major Urban Water Authorities of Australia.

Assessing a cloud seeding experiment

Residents of Melbourne pay approximately $400 for each megalitre of water they consume. These charges are among the highest in Australia. With water use growing at about 2% per year, Melbourne Water is keen to augment its supplies without the enormous cost of new water storage projects.

The Division is analysing data from a five-year experiment designed to show to what extent cloud seeding increases precipitation over the main Thomson catchment area. This area was chosen partly because of the presence of orographic clouds produced by the Baw Baw Plateau and neighbouring ridges forming the western boundary of the catchment.

Intensive observational programs were conducted in 1988 and 1990. Sophisticated monitoring equipment was installed within and around the catchment area.

The Bureau of Meteorology supplied an Omegasonde unit to describe atmospheric structure during winter storms. The CSIRO research aircraft sampled clouds at various heights, providing a thorough picture of cloud and precipitation development. Melbourne Water and the Division provided computer-recording rain gauges.

A microwave radiometer from the United States measured the amount of liquid water present in clouds. Liquid water measurements are necessary for deciding whether seeding is likely to be effective. Subsequently, the Division constructed its own radiometer for the experiment.

Although statistical analysis of seeding effects is still underway, the research has shown that the post-cold-front part of a winter storm provides the best opportunity for seeding. Under these conditions, about 600 megalitres of super-cooled liquid water is available for precipitation each hour. This demonstrates the very large potential benefit of cloud seeding.

SUPPORT SERVICES

Administration

The administrative group provides human and financial resources support to the Division including staff recruitment, budgeting, purchasing and stores, word processing, reception, travel and transport facilities. It also supports the commercialisation of our research by providing negotiation and contract services.

The devolving of many of the CSIRO corporate centre activities to Divisions has seen a rapid increase in the range of responsibilities of Divisional administrative staff and during the past two years many training programs have been undertaken to meet these new responsibilities.

A new human resources management system (CHRIS) was installed on our administrative computing system. This provides strategic human resources information for senior management and has increased the efficiency of current administrative functions.

Further work has been done on the provision of accurate and comprehensive financial data to all management levels. This is particularly vital due to the increasing range of funding sources and our obligations under environmental consulting contracts.

Planning commenced for a major site redevelopment program to commence in the 1992–93 financial year that will provide new laboratories and a permanent home for the administrative group and consolidate the stores, canteen, lecture theatre, administration, library and executive offices in one central area. This will create more integrated and efficient accommodation for these vital services.

Computer Services Group

Powerful computer systems linked together by high-speed networks are important tools supporting the Division's research activities. Scientists have access to a network of locally installed computer servers and graphics workstations, as well as remote supercomputers. On their desktop, most staff have either a PC, X-terminal, or UNIX workstation connected to the Divisional local area network. Access to the CSIRO's CRAY Y-MP supercomputer, located in Melbourne, is provided by a 2 Mb per second link. This also connects the Divisional network to the Australian Academic Research Network (AARNet), providing world-wide interactive access to remote computers, electronic mail, file transfer and news group services.

The Computer Services Group provides a wide range of computing and network services. A computer machine-room houses a range of computer servers and data communications equipment. This facility operates 24-hours-a-day, and is protected by a recently installed fire extinguisher system and an electronically-controlled security system.

Other services provide by the Group include installation and maintenance of an extensive local area network and its connection to AARNet, general support for desktop equipment, as well as staff training.

Engineering Facilities Group

The Engineering Facilities Group encompasses electronic design and construction, mechanical design and construction, and site engineering.

Electronic Design Facility

Design capabilities have been upgraded by the incorporation of a number of software packages, thus producing an integrated computer aided design (CAD) system. The Facility's design portfolio now includes computer-aided circuit and mechanical drafting, printed circuit design, and analog and digital circuit simulation. In addition, electronically programmable logic devices are employed.

Listed below are a number of recently completed key projects, all of which have involved the integrated CAD system.

Airborne Hazard Detection System
A major achievement has been the construction of the Airborne Hazard Detection System which has been tested in Tasmania and Japan.

CSIRO Intelligent Data Telemetry System
The CSIRO Intelligent Data Telemetry System (CSIDAT) consists of eight stations telemetering data to a central station. The data are then telemetered to NOAA satellites. CSIDAT is solar powered and fully self-contained. CSIDAT is being used to verify surface temperature measurements made by satellites.

Craig Smith in the Mechanical Laboratory fabricating the support for a new satellite-tracking antenna.

Several systems are planned and the first has been installed at Hay in New South Wales.

Sea-surface profiler
A data-logging system was developed for investigating air–sea interaction. The data-logger recorded temperature at several points in the bottom two metres of the atmosphere and the top two metres of the ocean while being towed by the CSIRO research vessel, the RV *Franklin.*

Current electronics projects include the design of a radiometer for the Atmospheric Radiation Measurement (ARM) Project, sensors for the Southern Ocean Aircraft Experiment, instrumentation for the atmospheric pressure sensor, development of the mini-lidar and fibre-optic laser interface equipment.

Mechanical Laboratory

Major achievements include the construction of a large towing tank and filling system for the Geophysical Fluid Dynamics Laboratory. The tank, measuring 4 m × 2 m × 0.4 m, was designed for studying flow over topography.

Extensive work for GASLAB and ICELAB has improved automation and efficiency of atmospheric trace gas measurements.

Mechanical Design

The Division's machining facility has been strengthened by the introduction of CAD systems. Currently, a major project is the design of a multi-wavelength scanning lidar for studying optical properties of clouds and aerosols, and for tracking smoke plumes.

Site Services

Major projects have included the construction of GASLAB and the refurbishment of the CSIDA satellite reception laboratory. The Site Services Group will play a major role in the forthcoming redevelopment of the Aspendale site.

Scientific Services Group

The Scientific Services Group supports the Divisional research effort through the provision of public relations activities, as well as editorial, graphics, photography, and library services. The Group maintains and fosters interactions with a wide variety of stakeholders.

Communication

The Group's communication activities are designed to facilitate recognition of the quality and importance of the Division's scientific work. Objectives of the Group also include the generation of income in support of our research, commercial exploitation of techniques and instruments, and encouragement of collaborative research activities.

The Division plays a major role in providing independent, authoritative information on a range of scientific issues. The Group regularly presents media briefings and issues press releases. In addition, presentations are made at conferences and various public gatherings.

Publications

The Group produces the biennial Research Report, our external newsletter, the *DAR Bulletin*, and an internal newsletter. Assistance is a also provided for the production of technical papers, policy papers and other reports.

To meet a large demand for accurate, up-to-date information on a range of topical issues relevant to atmospheric research, information papers (brief

Divisional librarian, Ms Liz Davy, cataloguing the Division's latest acquisitions

overviews examining specific topics) and information sheets (general information) are frequently produced and updated.

Graphics and photography

The Group supports the Division's requirements for high quality audio-visual material. The photography and graphics section assists with preparation for scientific publications and presentations.

Divisional graphic artists provide support for technical and scientific illustrations for publications, seminars and conference presentations. Increasingly, they are assisting in the preparation of high quality posters for conferences.

The Divisional photographer provides material for publications and presentations. The provision of video services is expanding rapidly, and has resulted in a number of high-quality video recordings demonstrating and illustrating the Division's research activities.

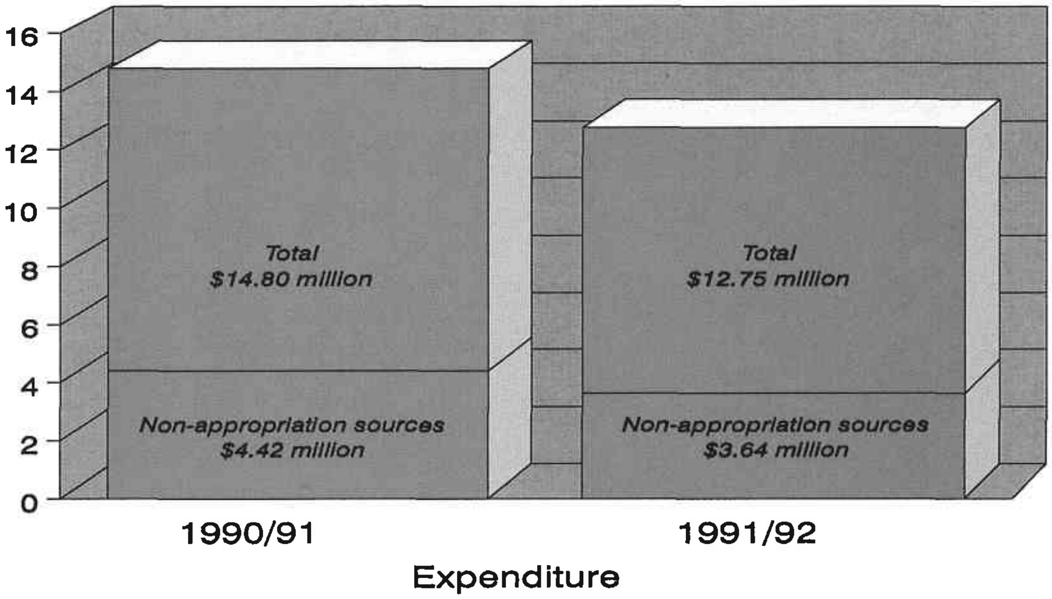
Divisional library

The Division maintains an extensive library which operates as part of the Australia-wide CSIRO library network and provides a full range of services to users. The library is a full participant in CLINES, CSIRO's integrated on-line automated library system. A project team to plan for the next generation system has been set up and we will be heavily involved through the Divisional Librarian's membership of that team.

In 1991, the Library cooperated with the CSIRO Management Information Systems Branch to develop CLASS (CLINES Local Auxiliary Search System), a microcomputer-based catalogue which has been widely adopted throughout CSIRO libraries. The library has taken over responsibility for the Division's publication and reprint collections and has developed a series of machine-readable databases of all publication since our foundation in 1946.

Plans for the construction of a new library are now finalised and it is anticipated that the new premises will be ready early in 1994.

FINANCES



The Division's total expenditure for 1990–91 was $14.80 million, after deducting construction costs of the Climate Research Laboratory. Non-appropriation sources represented 33.7% of expenditure. In 1991–92, total expenditure was $12.75 million, after deducting abnormal expenditure associated with supercomputer writeback. Non-appropriation sources accounted for 34.9% of expenditure.

Research grants and external funds

Contributor	1990–91 ($)	1991–92 ($)
Association of Fluorocarbon Consumers and Manufacturers	25 000	
Australian National University (NGAC)		50 500
Australian Water Resources Advisory Council	10 000	74 846
Bureau of Meteorology	187 200	357 255
Conservation Commission of the Northern Territory	107 800	113 514
Cotton Research and Development Corporation		60 000
Defence Science and Technology Organisation	15 000	16 000
Department of Agriculture and Rural Affairs (Vic.)	75 045	24 172
Department of Conservation, Forests and Lands (Vic.)		48 000
Department of Industry, Technology and Commerce	80 100	62 570
Department of Primary Industry and Energy	155 632	18,695
Department of the Arts, Sport, the Environment and Territories	1 465 249	1 151 882
Department of Water Resources (NSW)		10 000
Electricity Commission (NSW)	15 000	31 346
Electricity Commission (WA)	97 445	19 219
State Pollution Control Commission (NSW)	107 800	113 514
Environment Protection Authority (Vic.)	229 000	187 927
Environment Protection Authority (WA)	110 000	121 854
Melbourne Water	151 000	145 938
Mount Isa Mines Ltd		35 000
Rural Industries Research and Development Corporation		45 000
Shell Company Australia Ltd	30 000	30 000
State Electricity Commission (Vic.)	79 085	213 026
Tenaga Nasional Berhad (Malaysia)		24 450
United States Department of Energy		18 314
University of New South Wales (ARC)	27 699	58 843
Wool Research and Development Fund	130 813	131 303
Other grants and consultancies	213 000	293 501
Contributions in kind (Mainly overseas travel)	120 000	120 000
Total	**3 431 867**	**3 576 669**

VISITORS

Short-term visitors

Dr Tom Ackerman, Pennsylvania State University, USA
Dr H. Akimoto, Environment Agency of Japan
Prof. Jorge de las Alas, University of the Philippines
Ms Leonie Andrews, Department of Industry, Technology and Commerce
Mr S. Araki, Environment Agency of Japan
Mr Gary Banks, Industry Commission
Mr John Beard, Bureau of Meteorology
Mr George Beardsley, Department of Industry, Technology and Commerce
Dr Henry Berko, California State University, USA
Prof. S.K. Bhattacharya, Physical Research Laboratory, India
Dr Roger Bird, Australian Nuclear Science and Technology Organisation
Mr Giorgio Boggio, Commission of the European Communities
Dr Carl Brenninkmeijer, Department of Scientific and Industrial Research, New Zealand
Dr Edward Browell, NASA Langley Research Center, USA
Dr Brendan Buckley, Columbia University, USA
Mr Alex Campbell, Senior Vice President, Western Australian Farmers' Federation
Dr Frank Carnovale, Environment Protection Authority of Victoria
Dr Tom Casedevall, US Geological Survey, USA
The Hon. Fred Chaney, Shadow Minister for the Environment
Dr Bern Chapman, CSIRO Division of Coal and Energy Technology
Dr John Chappell, Australian National University
Dr Ric Charlton, Chairman and Chief Executive Officer, Shell Australia Limited
Dr Peter Chester, Executive Director, National Power Company, UK
Mr Andrew Chisholm, Research Fellow, Tasman Institute
Dr Paul Christianson, Boeing Corporation, USA
Dr Ed Cook, Columbia University, USA
Mr Martin Cope, Environment Protection Authority of Victoria
Mr Michael Crowe, Victorian Government Greenhouse Unit
Dr Noel Davidson, Bureau of Meteorology
Dr Jim Easson, Bureau of Meteorology
Dr Dan Endres, National Oceanic and Atmospheric Administration, USA
Dr Carl Erickson, Boeing Corporation, USA
Dr Noel Ethridge, Aberdeen Research Centre, Scotland
Dr David Farmer, Institute of Ocean Studies, Canada
Dr Graham Farquhar, Australian National University
Prof. Paolo Fasella, Director-General of Science, Research and Development, Commission of the European Communities
Dr Eldon Ferguson, National Oceanic and Atmospheric Administration, USA
Dr Kevin Folley, CSIRO Board Member
Dr Bruce Forgan, Bureau of Meteorology
Dr Y. Fujinuma, Environment Agency of Japan
Dr Doug Gauntlett, Deputy Director, Bureau of Meteorology
Mr Bruce Gooday, Industry Commission
Dr Don Grainger, Department of Scientific and Industrial Research, New Zealand
Prof. David Green, Science Adviser to the Hon. Ros Kelly
Dr Roy Green, Director, CSIRO Institute of Natural Resources and Environment
Mr Alan Hall, Snowy Mountains Hydroelectric Authority
Dr Malcolm Hall, Multifunction Polis
Mr Bohdan Harasymiw, State Electricity Commission of Victoria
Mr Bill Hare, Australian Conservation Foundation
Dr Graham Harris, Director, COSSA
Prof. Stuart Harris, Australian National University
Prof. Peter Hartley, Research Fellow, Tasman Institute
Dr John Head, Australian National University
Dr Dennis Hearn, Environment Protection Authority of Victoria
Dr David Heggie, Bureau of Mineral Resources
Mr Wayne Hennessy, Coal Research Association of New Zealand
Dr Peter Hertan, General Manager, Energy Victoria
Mr John Heussler, Grazier, Queensland
Dr Bruce Hicks, National Oceanic and Atmospheric Administration, USA
Ms Wakako Hironaka, Japanese Parliamentary Delegation on the Environment
Dr Greg Holland, Bureau of Meteorology
Dr Peter Howarth, Department of Foreign Affairs and Trade
Dr Hu Tao, Inner Mongolia Meteorological Service Centre
Mr David Hughes, Manager, Environmental Affairs, Mount Isa Mines Ltd
Mr Huynh Nguyen Lan, Hydrometeorological Service, Vietnam
Mr Huynh Van Anh, Hydrometeorological Service, Vietnam
Mr Neil Inall, Media Consultant, Sydney
Dr Gen Inoue, Environment Agency of Japan
Mr Amos Israeli, Israel Meteorological Service
Dr T. Ito, Japan Meteorological Agency
Dr John Ivey, Australian Government Analytical Laboratories
Dr K. Izumi, Environment Agency of Japan
Prof. Jimmy de Jager, University of the Orange Free State, South Africa
Prof. Paul Jarvis, University of Edinburgh, Scotland

Mr David Johns, Department of Primary Industries and Energy
Mr Graham Johnson, CSIRO Division of Coal and Energy Technology
Dr Wally Johnson, Bureau of Mineral Resources
Dr Bob Joynt, State Electricity Commission of Victoria
Dr John Keefer, Aberdeen Research Centre, Scotland
Dr Ralph Keeling, National Center for Atmospheric Research, USA
Mr Bryan Kelly, Shell Australia Limited
Mr Peter Kennedy, Deputy Secretary, Department of the Arts, Sport, the Environment, Tourism and Territories
Mr Douglas Laing, Executive Officer, Ambassador for the Environment
Dr Keith Lassay, Department of Scientific and Industrial Research, New Zealand
Mr Jim Le Cornu, Shell Australia Limited
Dr Paul Lehmann, Bureau of Meteorology
Dr John Le Marshall, Bureau of Meteorology
Mr Le Minh Duc, Hydrometeorological Service, Vietnam
Mr Le Nguyen Tuong, Hydrometeorological Service, Vietnam
Mr Le Quang Huynh, Hydrometeorological Service, Vietnam
Mr Li Sirong, Ministry of Agriculture, China
Dr Jennette Lindesay, University of Witswatersrand, South Africa
Mr Liu Duhui, State Meteorological Administration of China
Prof. Liu Qingsi, Beijing Normal University, China
Mr Liu Yutang, Heilongjiang Electric Power Bureau, China
Dr David Llewellyn-Jones, Rutherford Appleton Laboratory, England
Dr John Lloyd, Australian National University
Dr Geoff Love, Industry Commission
Dr David Lowe, Department of Scientific and Industrial Research, New Zealand
Mr Lu Zhao, Heilongjiang Electric Power Bureau, China
Prof. Mervyn Lynch, Curtin University, Western Australia
Prof. Greg MacCrae, Carnegie Melton University, USA
Prof. Dan MacNamara, University of the Philippines
Dr Martin Manning, Department of Scientific and Industrial Research, New Zealand
Mr Brian Martin, Manager, Victorian Government Greenhouse Unit
Dr H. Matsueda, Japan Meteorological Agency
Mr Koji Matsuura, Japanese Parliamentary Delegation on the Environment
Dr Ken McCracken, Australian Space Board
Mr Ian McFarlane, Shell Australia Limited
Mr Peter McGauran, Shadow Minister for Science and Technology
Dr Bruce Middleton, Executive Director, Australian Space Office
Dr Graham Mills, Bureau of Meteorology
Dr A.P. Mitra, Commonwealth Scientific and Industrial Research, India
Mr Des Moore, Acting Director, Institute of Public Affairs
Dr Alan Moran, Tasman Institute
Dr Brett Mullan, New Zealand Meteorological Service
Ms Michelle Murphy, Department of Foreign Affairs and Trade
Dr Mike Murray, Chief, CSIRO Division of Materials Science and Technology
Dr T. Nakazawa, Tohoku University, Japan
Mr Guiseppe Nastri, European Communities Delegation
Dr Nguyen Duc Ngu, Hydrometeorological Service, Vietnam
Dr Neville Nicholls, Bureau of Meteorology
Dr Y. Nojiri, Environment Agency of Japan
Dr Peter Novotny, Bureau of Meteorology
Dr Barry Osmond, Australian National University
Ms Wendy Parsons, Manager, Public Affairs and Communication, CSIRO Institute of Natural Resources and Environment
Dr Andrew Pik, Manager, Policy and Planning, CSIRO Institute of Natural Resources and Environment
Dr Cecily Rasmussen, James Cook University, Queensland
Dr Mike Raupach, CSIRO Centre for Environmental Mechanics
Dr Jim Renwick, New Zealand Meteorological Service
Mr Ed Roberts, Auspace
Mr James Roberts, Industry Commission
Dr Brian Robinson, Chairman, Environment Protection Authority, Victoria
Prof. Henning Rodhe, University of Stockholm, Sweden
Dr Keith Ryan, CSIRO Division of Applied Physics
Mr Kazuo Saito, Japanese Parliamentary Delegation on the Environment
Dr Hans Schneider, CSIRO Division of Applied Physics
Mr Barry Schultz, Director, Australian Fishing Enterprises
Dr Derek Scotney, Director, Soil and Irrigation Research Institute, South Africa
Ms Shu Huifen, Ministry of Energy, China
Dr Abraham Singels, University of the Orange Free State, South Africa
Dr Fred Singer, University of Virginia, USA
Dr W.L. Smith, University of Wisconsin, USA
Hon. Sir Ninian Stephen, Ambassador for the Environment
Prof. Graeme Stephens, Colorado State University, USA
Dr John Stocker, Chief Executive, CSIRO
Dr John Stone, Institute of Public Affairs
Dr Boyd Strain, Duke University, USA
Mr Akira Takahashi, Office of Meteorological Satellite Planning, Japan
Dr Y. Takeuchi, Environment Agency of Japan
Dr Takeshi Tanonaka, Global Environmental Forum, Japan
Mr Greg Thill, Manager, Human Resources and Finance, CSIRO Institute of Natural Resources and Environment
Dr Tian Xiting, State Space Office, China
Dr Bronte Tillbrook, CSIRO Division of Oceanography
Dr H. Tsuruta, Ministry of Agriculture, Forestry and Fisheries, Japan
Dr Claudio Tuniz, Australian Nuclear Science and Technology Organisation
Dr Ian Tuohy, British Aerospace,Australia
Dr H. Ueda, Kyushu University, Japan
Dr T. Uehiro, Environment Agency of Japan
Dr M. Utiyama, Environment Agency of Japan
Dr Akula Venkatram, ENSR Consulting and Engineering, USA

Dr Bob Walko, Colorado State University, USA
Ms Penny Wensley, Department of Foreign Affairs and Trade
Dr Stuart Whittlestone, Australian Nuclear Science and Technology Organisation
Dr Garry Willets, University of Sydney
Prof. Martin Williams, Monash University
Mr Bob Wilson, Managing Director, NSW Water Board
Dr Ian Wilson, CSIRO Division of Materials Science and Technology
Dr Stephen Wilson, Wollongong University
Dr Wu Peizhong, Second Institute of Oceanography, China
Mr Xu Dingfeng, China Electricity Council
Dr S. Yamamoto, Ministry of International Trade and Industry, Japan
Dr Yu Guohui, State Oceanic Administration, China
Mr Yu Lixing, Ministry of Energy, China
Dr Yu Yunyue, Ocean University of Qingdao, China
Dr Zhang Hongxiang, Second Institute of Oceanography, China
Mdm Zhang Miaoling, Jiangsu Provincial Academy of Agricultural Sciences, China
Mdm Zhang Ming, Ministry of Agriculture, China
Mdm Zhang Qiaoling, Ministry of Agriculture, China
Mr Zhang Wei, Beijing Agricultural University, China
Dr Zhou Changbao, Second Institute of Oceanography, China
Dr John Zillman, Director, Bureau of Meteorology

Longer-term scientific visitors

Prof. Bill Cotton, Department of Atmospheric Science, Colorado State University, USA
22 February – 9 April 1991
Dr Jim Elkins, National Oceanic and Atmospheric Administration, USA
29 November – 14 December 1990
Dr Keith Lassey, National Institute of Water and Atmospheric Research, New Zealand
5 September – 14 September 1992
Prof. Li Chongyin, Institute of Atmospheric Physics, Academy of Science, Beijing, China
9 November 1991 – 11 April 1992
Dr David Lowe, National Institute of Water and Atmospheric Research, New Zealand
6 February – 15 February 1992
Prof. Soon-Ung Park, Department of Atmospheric Sciences, Seoul National University, Republic of Korea
15 December 1991 – 13 February 1992
Prof. Stuart Penkett, School of Environmental Sciences, University of East Anglia, England
17 January – 14 February 1991
Prof. Paul Quay, School of Oceanography, University of Washington, USA
2 January – 30 March 1992
Mr Roger Ridley, Industrial and Environmental Meteorology Section, New Zealand Meteorological Service
3 March – 16 April 1992
Prof. Shang Shuhui, Institute of Applied Ecology, Academy of Science, China
21 January – 17 August 1991
Dr Pieter Tans, National Oceanic and Atmospheric Administration, USA
9 March – 18 March 1992
Dr Neil Trivett, Atmospheric Environment Services, Canada, Gas Standards Laboratory, Canada
9 March – 24 March 1992
Dr Tsuneharu Yonetani, Head, Climate Change and Impacts Laboratory, National Research Institute for Earth Science and Disaster Prevention, Ibaraki-Ken, Japan
16 March – 2 April 1992

AFFILIATIONS

The committees, panels and editorial boards on which staff members served are listed below.

Allan, Robert
Committee Member, Australian Meteorological and Oceanographic Society (AMOS)

Ayers, Greg
Associate Editor, *Clean Air*
Member, International Association for Meteorology and Atmspheric Physics (IAMAP) Commission on Atmospheric Chemistry and Global Pollution
Member, Steering Committee, International Global Atmospheric Chemistry's APARE Activity
Convener, International Global Atmospheric Chemistry's DEBITS Activity

Baines, Peter
Associate Editor, *Australian Meteorological Magazine*
Member, Editorial Board, *Dynamics of Atmospheres and Oceans*
Member, International Commission for Dynamic Meteorology
Member, International Commission for Dynamic Meteorology, Working Group C (Mesoscale Dynamics)

Barton, Ian
Member, UK–France–Australia Along Track Scanning Radiometer (ATSR) Science Team
Member, MODIS Science Team for NASA's Earth Observing System (EOS)

Beer, Tom
Associate Editor, *Australian Meteorological Magazine*, *International Journal of Wildland Fire*
Editorial Board, *Environment International*
Editor-in-Chief, AMOS publications
Member, AMOS Council
Chairman, AMOS Awards and Publications Committees

Bouma, Willem
Member, Cape Grim Baseline Air Pollution Station (CGBAPS) Working Group
Member, Australia and New Zealand Environment Council (ANZEC) Greenhouse Task Force
Member, Judging Panel for 1990 BHP Prize
Secretary, Divisional Advisory Committee

Davy, Liz
Chairman and Victorian representative, CLINES User Group
Member, CSIRO Next Library System Project Team

Francey, Roger
Guest Editor, *Journal of Atmospheric Chemistry*
Consultant, International Atomic Energy Agency, Vienna

Fraser, Paul
Member, Working Group 1, Intergovernmental Panel on Climate Change
Chairman, Measurements and Trends Group, NASA CFC and Halon Trends, Emissions and Lifetime Assessment
Chairman, Source gases: Emissions and Trends Group, UNEP/WMO 1991 Ozone Assessment
Convener, Trace gas intercalibrations and intercomparisons project, IGBP, International Global Atmospheric Chemistry (IGAC) Core Project
Member, Advanced Global Atmospheric Gases Experiment (AGAGE)
Member, CGBAPS Working Group
Member, ANZEC Ozone Protection Consultative Committee
Member, Commission for Atmospheric Sciences (WMO) Working Group on Environmental Pollution and Atmospheric Chemistry

Frederiksen, Jorgen
Member, Editorial Committee, *Quarterly Journal of the Royal Meteorological Society*

Galbally, Ian
Member, CGBAPS Working Group
Member, Scientific Advisory Commitee SCOPE Biospheric Trace Gas Emissions Project
Secretary, International Commission on Atmospheric and Global Pollution, IAMAP
Member, Scientific Steering Committee of the IGAC Project
Member, Expert Group on Greenhouse Gases of the Joint Scientific Committee of the World Climate Research Program
Member, Executive Committee NASA Global Tropospheric Experiment — Pacific Exploratory Mission
Chairperson, Australian Update of IPCC Working Group 1, Greenhouse Gases and Climate Forcing
Associate Editor, *Journal of Atmospheric Chemistry*
Member, Editorial Board, *Tellus*

Garratt, John
Member, Editorial Board of *Boundary Layer Meteorology*
Member, International Commission on Dynamic Meteorology, IAMAP

Gras, John
Member, CGBAPS Working Group
Member, IGAC Multi-Phase Atmospheric Chemistry Committee
Member, WMO GAW Aerosol Expert Panel
Member, IAMAP Committee on Nucleation and Atmospheric Aerosols
Member, Global Aerosol Climatology and Effects Program (GACEP) Stratospheric Aerosol Committee

Hughes, Roger
Editor, *Pure and Applied Geophysics*
Corresponding Member, WMO Commission for Atmospheric Sciences, Medium- and Long-Range Weather Prediction Research

Hunt, Barrie
Member, National Committee for Climate and Atmospheric Change
Discipline member, Scientific Committee on Solar-Terrestrial Physics
Associate Editor, *Climate Dynamics*

Jensen, Jørgen
Member, Aircraft Advisory Committee, CSIRO Office of Space Science and Applications (COSSA)

Manins, Peter
Associate Editor, *Clean Air*

Pearman, Graeme
Vice-President, Australian Meteorological and Oceanographic Society
Member, Australian Academy of Science National Committee for Climate and Atmospheric Sciences
Member, Australian Academy of Science National Committee for the International Geosphere-Biosphere Program (IGBP)
Member, Society of Automotive Engineers, Australia, Environmental Pollution Advisory Committee
Member, CGBAPS Working Group
Member, IGBP Working Group on Global Change System for Analysis Research and Training (START)
Board Member, Climate Institute, Washington, DC
Member, South Australian Sea-Level Advisory Committee
Chairman, Organisers' Panel, Dahlem Konferenzen, 9–14 December 1990

Pittock, Barrie
Member, Australian National Committee for the Environment
Member, IAMAP/IUGG International Commission on Climate
Initiator, Project 5: Australia–UK–New Zealand Tripartite Agreement on Collaboration on Climate Change
Member, Editorial Boards, *Journal of Natural Hazards*, *Climate Change*, *International Journal of Climatology*
Member, Asian Region Modelling Group, IGBP

Platt, Martin
Member, IAMAP International Radiation Commission, Rapporteur on Clouds and Radiation
Member, International Committee for Laser Atmospheric Studies
Executive Member, International Commission on Cloud Physics
Chairman, Scientific Committee for the International Experimental Cloud Lidar Pilot Study (ECLIPS)
Member, Scientific Committee for the Lidar in Space Technology Experiment (LITE)
Chairman, Australian Institute of Physics Remote Sensing Group
Member, Australian Academy of Science National Committee on the Global Energy and Water Cycle Experiment (GEWEX)

Prata, Fred
Member, IGBP Working Group on Land Surface Temperatures
Member, Along Track Scanning Radiometer for ERS-1, ESA Science Team

Ryan, Brian
Member, Aircraft Advisory Committee, COSSA

Sawford, Brian
Leader, Non-Reactive Gases Project Team, Latrobe Valley Airshed Study
Member, Editorial Committee, *Quarterly Journal of the Royal Meteorological Society*
Member, American Meteorological Society Committee on Boundary Layer and Turbulence

Smith, Ian
Editor, *AMOS Bulletin*
Corresponding Member, WMO Commission for Atmospheric Sciences, Medium- and Long-Range Weather Prediction Research

Steele, Paul
Member, AGAGE
Member, CGBAPS Working Group

Tucker, Brian
President, IAMAP
Executive Member, Scientific Committee on Oceanogrphic Research (SCOR)
Fellow, Australian Academy of Technological Sciences and Engineering
Member, National Greenhouse Advisory Committee (NGAC)
Member, COSSA Advisory Board
Member, ANZEC Standing Committee
Member, National Committee for Climate and Atmospheric Sciences (NCCAS)
Member, Editorial Board, *ACTA Meteorologica Sinica*

Turner, Peter
Member, Victorian Remote Sensing Committee

CONFERENCES

Conferences and Workshops supported by the Division

Workshop on Carbon Storage by Terrestrial Biota and Soils, Aspendale, 18 July 1990
Convener: Dr Roger Francey

Australian Climate Research: Present and Future, Melbourne University, 27–28 November 1990
Convener: Dr Ian Simmonds

Workshop on Ice Core Research Progress, Aspendale, 11 December 1990
Conveners: Dr Roger Francey and Mr David Etheridge

Climate Change Research Program Annual Review, Aspendale, 9–10 May 1991
Convener: Dr Graeme Pearman

ASCA Workshop on Greenhouse Gases and Climate Change: An Asian Perspective, Melbourne, 17–21 June 1991
Conveners: Dr Graeme Pearman and Dr Willem Bouma

Workshop on the Climatic Impact of the Mt Pinatubo Eruption, Aspendale, 16 October 1991
Convener: Dr Ian Barton

International Conference on the Physical Causes of Drought and Desertification, Melbourne University, 9–13 December, 1991
Convener: Mr Barrie Hunt

Fourth Air–Sea Interaction Conference, Melbourne, 3–6 February 1992
Convener: Dr Peter Baines

Third Australasian Conference on the Physics of Remote Sensing of Atmosphere and Oceans, Melbourne University, 10–14 February 1992
Convener: Dr Martin Platt

Workshop on Tasmanian Tree Rings, Aspendale, 2 March 1992
Convener: Dr Roger Francey

Trace Gas Measurement in Both Hemispheres, Aspendale, 11–13 March 1992
Conveners: Dr Greg Ayers and Dr Paul Fraser

The Carbon-13 Constraint on the Global Carbon Budget, Aspendale, 16 March 1992
Convener: Dr Roger Francey

Workshop on Agriculture and Greenhouse in South-Eastern Australia, Aspendale, 18–19 March 1992
Convener: Mr Ian Galbally

Workshop on Inverse Modelling Problems in Atmospheric Constituent Transport, Aspendale, 20 March 1992
Convener: Dr Ian Enting

DSIR/CSIRO Chief Executives' Symposium on Atmospheric Research, Queenstown, New Zealand, 22–24 April 1992
Conveners: Dr Brian Tucker, Dr Willem Bouma

Climate Change Research Program Annual Review, Aspendale, 20–22 May 1992
Convener: Dr Graeme Pearman

Workshop on the El Niño – Southern Oscillation, Melbourne, 15 June 1992
Convener: Mr Barrie Hunt

Overseas conference presentations

The following is a list of overseas conference presentations by Divisional staff. An indication of the number and range of presentations in Australia can be found in the many references to conference proceedings in the publications section of this Report.

1990

International TOGA Scientific Conference, Honolulu, Hawaii, July
Hirst, A.C. 'On simple coupled ocean atmosphere models, equatorial instabilities and ENSO'

AMS Cloud Physics Conference, San Francisco, California, USA, July
Jensen, J.B. 'The 1988 Australian Winter Storms Experiment: case study: 6 August 1988"
Jensen, J.B. and LeMone, M.A. 'Some aspects of the structure and dynamics of Hawaiian cloud bands'

Malaysian Science Congress, Kuala Lumpa, Malaysia, August
Pittock, A.B. 'The greenhouse effect: global and regional impacts'

Third ECLIPS Workshop, Pirano, Italy, October
Platt, C.M.R. 'Report on the Third ECLIPS Workshop, Porano, Italy, 25-27 October 1990'

Fourth International Workshop on Multiple Scattering in Lidar Experiments, Florence, Italy, October
Platt, C.M.R. and Young, S.A. 'Multiple scattering in the overlap region of a lidar system: calculations and observations in stratus fog'

1991

International Conference on Climatic Impacts on the Environment and Society, Tsukuba, Japan, January
Pittock, A.B. 'Developing regional climate change scenarios'

71st American Meteorological Society Annual Meeting, New Orleans, USA, January
Young, S.A., Cutten, D.R., Lynch, M.J. and Davies, J.E. 'Lidar derived backscatter and extinction of maritime aerosols'

NOAA, CMDL Annual Meeting, Boulder, Colorado, USA, March
Gras, J.L. 'Southern ocean atmospheric condensation nucleus programme: some results'

19th Conference on Hurricanes and Tropical Meteorology, Miami, Florida, USA, May
Evans, J.L. 'Tropical cyclone sensitivity to sea-surface temperatures'

Fifth Conference on the Meteorology and Oceanography of the Coastal Zone, Miami, Florida, USA, May
McInnes, K.L. and McBride, J.L. 'On the forcing mechanisms of the Southerly Buster'

Symposium on Tropospheric Chemistry of the Antarctic Region, Boulder, Colorado, USA, June
Etheridge, D.M., Pearman, G.I. and Fraser, P.J. 'Changes in tropospheric methane between 1840 and 1980, from a high cumulation-rate ice core'
Clarkson T. and Fraser, P.J. 'Vertical profiles of trace gases in the Antarctic troposphere'
Conway T.J. and Steele, L.P. 'The changing composition of the Antarctic troposphere. Carbon dioxide and methane distributions and variations'

Gordon Research Conference on Atmospheric Chemistry, New Hampton, New Hampshire, USA, June
Fraser, P.J. 'Distribution and trends of greenhouse gases and related tracers'

First International Symposium on Volcanic Ash and Aviation Safety, Seattle, Washington, USA, July
Prata, A.J. and Barton, I.J. 'Detection and discrimination of volcanic ash using infrared radiometry. Part 1: theory. Part 2: experimental'

NASA Meeting on Trends and Lifetimes of CFCs, HCFCs, Halons and Related Species, Newport Beach, California, USA, July
Fraser, P.J. 'Trends and global distributions of CFCs, HCFCs, halons and related species'

International Conference on Parallel Computing, London, England, August
Frances, R., Abramson, D., Rotstyn, L.D. and Dix, M.R. 'SIMD climate modelling'

IAMAP Symposium on Aerosol–Cloud Climate Interaction, Vienna, Austria, August
Boers, R. 'Atmospheric feedback in stratocumulus clouds'
Lemus, L., Platt, C.M.R., Jensen, D. and Budd, W.F. 'Cloud radiative forcing in a general circulation model'
Platt, C.M.R.' The ECLIPS experiment — lidar sensing of cloud properties from the ground'
Platt, C.M.R., Young, S.A. and Patterson, G.R. 'Observations of cloud height and extinction coefficient in Australia in the ECLIPS experiment'
Platt, C.M.R. and Arking, A. 'Small particles in cirrus clouds in the first FIRE experiment'

NATO Workshop on the Global Carbon Cycle, Il Ciocco, Italy, September
Enting, I.E. and Pearman, G.I. 'Average global distributions of carbon dioxide'

International Symposium on the Little Ice Age Climate, Tokyo Japan, September
Cook, E., Bird, T., Peterson, M., Barbety, M. and Francey, R.J. 'The little ice age in Tasmanian tree rings'

35th Oholo Conference, Eilat, Israel, October
Sawford, B.L. 'Recent developments in the Lagrangian stochastic theory of turbulent dispersion'

19th International Technical Meeting of NATO-CMS on Air Pollution Modelling and its Application, Crete, Greece, October
Physick, W.L., Noonan, J.A., Manins, P.C., Hurley, P.J. and Malfroy, H. 'Application of coupled prognostic windfield and Lagrangian dispersion models for air quality purposes in a region of coastal terrain'

CHAMPP Workshop on Fluid Flow on the Sphere, Boulder, USA, October
McGregor, J.L. 'An economical procedure for determining departure points on the sphere'

Fifth Conference on Climate Variations, Denver, USA, October
McGregor, J.L. and Walsh, K.J. 'Summertime climate simulations for the Australian region using a nested model'

Global Climate Change, its Mitigation through Improved Production and Use of Energy, Los Alamos, New Mexico, USA, October
Whetton, P.H. 'Toward regional climate change scenarios: how far can we go?'

UNEP/WMO Stratospheric Ozone Assessment Meeting, Les Diablerets Switzerland, October
Fraser, P.J. 'Trends and global distributions of ozone depleting trace gases'

Climate System Modelling Program Workshop, Fort Collins, USA, October
Garratt, J.R. 'Surface net radiation: models versus observations'

Simulation of Interannual and Intraseasonal Monsoon Variability, Boulder, Colorado, October
Gordon, H.B. 'A comparison of five climate simulations produced by the CSIRO9 model with MONEG 1987–88 SST anomalies against a ten-year model climatology'

ENEA Conference, Italy, October
Hunt, B.G. 'Greenhouse modelling at the CSIRO Division of Atmospheric Research'

OSA Topical meeting on Optical Remote Sensing of the Atmosphere, Williamsburg, Virginia, USA, November
Young, S.A., Patterson, G.R. and Manson, P.J. 'Lidar measurements of the evolution of the Mt. Pinatubo aerosol cloud over Melbourne, Australia'
Platt, C.M.R. 'The Experimental Cloud Lidar Pilot Study (ECLIPS) Program'

44th Annual Meeting of the Division of Fluid Dynamics, American Physical Society, Scottsdale, Arizona, November
Evans, J.L. 'Structure changes of an axisymmetric vortex under an imposed absolute vorticity gradient'

ARM Science Team Meeting, Denver, Colorado, USA, November
Platt, C.M.R. 'Use of ECLIPS techniques in the ARM program'

AGU Fall Meeting, San Francisco, USA, December
Gras, J.L. 'CN and CCN in Southern Ocean air: is there a proportional relationship with DMS?'

WMO GAW Aerosol Experts Meeting, Boulder, USA, December
Gras, J.L. 'The Cape Grim Aerosol Program'

International Conference on Mesoscale Meteorology and TAMEX, Taipei, Taiwan, December
Katzfey, J.J. 'An Australian east coast low: sensitivity study and energetics'
Katzfey, J.J. 'Storm-relative isentropic frontogenesis: the importance of synoptic-scale vertical motion'
Orlanski, I. and Katzfey, J.J. 'Development of a cyclone wave in the South Pacific'

1992

Third Symposium on Global Change Studies, Atlanta, USA, January
Walsh K.J., McGregor, J.L., Katzfey, J.J. and Rotstayn, L.D. 'Modelling climate change over Australia with a nested model'

NASA Climate Satellite Workshop, New York, USA, February
Gras, J.R. 'Tropospheric Aerosol'
Gras, J.R. 'CN/CCN Climatologies'
Gras, J.R. 'WMO GAW Programme'

Atmospheric Modelling Intercomparison Meeting, San Francisco, California, USA, February
Hunt, B.G. 'Chaotic influences on multi-annual simulations'

DSIR/CSIRO Chief Executives' Symposium on Atmospheric Research, Queenstown, New Zealand, April
Abbs, D.J. 'Applications of a nested numerical model to catchment size regions'
Enting, I.G. 'Modelling long-lived greenhouse gases in the global atmosphere'
Gras, J.L. 'Southern Ocean and Antarctic aerosol studies'
Jensen, J.B. 'The parameterisation of precipitation in numerical models: verification using in-cloud observations'
Katzfey, J.J. 'A simulation of an Australian east-coast low: sensitivity to physical parameterization'
Ryan, B.F. 'The problems of modelling extreme precipitation associated with tropical storms'
Tucker, G.B. 'A strategy for using numerical models to determine probable maximum precipitation over catchment-size regions'

Fifth AGAGE Meeting, Ballynahinch, Ireland, May
Steele, L.P. 'Analysis of Cape Grim and calibration of GAGE methane data'

Fourth ECLIPS Workshop, Toronto, Canada, May
Platt, C.M.R. 'Scientific and Climate Applications in ECLIPS'
Platt, C.M.R. 'Report on the Fourth ECLIPS Workshop, Toronto, May 1992'

World Congress of Dermatology, New York, USA, June
Marks, R. and Fraser, P.J. 'Ozone depletion and human health: fact or fiction?'

Symposium on the Tropospheric Chemistry of the Antarctic Region, Boulder, Colorado, USA, June
Etheridge, D.M. 'Changes in tropospheric methane between 1841 and 1978 from a high accumulation-rate Antarctic ice core'

Lecture courses presented at Australian tertiary institutions

Beer, Tom
University of Melbourne
1991, *Physics of the Oceans* to Third Year Science students (13 lectures)
1992, *Physics of the Oceans* to Third Year Science students (13 lectures)
1992, *Micrometeorology* to Third Year Meteorology students (13 lectures)

Galbally, Ian
University of Melbourne
1991, *Atmospheric Chemistry* to Masters Chemical Engineering students. Course included lectures by **Greg Ayers** and **Paul Fraser** (12 lectures)
1992, *Air Pollution Measurement* to Masters Chemical Engineering students. Course included lectures by **John Gras** (12 lectures)

Garratt, John
Monash University
1990, 1991, 1992, *The Atmospheric Boundary Layer* to Honours and Masters Science students (22 lectures)

Hughes, Roger
University of Melbourne
1991, *Geophysical Fluid Dynamics* to Fourth Year Mathematics students (13 lectures)

McGregor, John
Monash University
1990, *Atmospheric Environment* to Third Year Mathematics students (20 lectures)

Ryan, Brian
University of Melbourne
1990, 1991, *Tropical Clouds and Cloud Systems* to Honours and Graduate Meteorology students (10 lectures)

Smith, Ian
University of Melbourne
1990, 1991, 1992, *Solar and Terrestrial Radiation* to Third Year Meteorology students (13 lectures)

PUBLICATIONS

Allan, R.J., Beck, K. and Mitchell, W.M. (1990). Sea level and rainfall correlations in Australia: tropical links. *Journal of Climate*, **3**(8), 838–846.

Allan, R.J. (1991). Australasia [Regional case studies of teleconnections: physical aspects]. In M.H. Glantz, R.W. Katz and N. Nicholls (editors.), *Teleconnections linking worldwide climate anomalies: scientific basis and societal impact*. p. 73–120. Cambridge: Cambridge University Press.

Allan, R.J., Nicholls, N., Jones, P.D. and Butterworth, I.J. (1991). A further extension of the Tahiti–Darwin SOI, early ENSO events and Darwin pressure. *Journal of Climate*, **4**(7), 743–749.

Allan, R.J., Mitchell, C.D. and **Pittock, A.B.** (editors). (1992). *The greenhouse effect: regional implications for Western Australia: annual report, 1990–91*. [Aspendale, Vic.]: CSIRO; W.A. Environment Protection Authority.

Allison, C.E., Cramer, J.E., Hop, C.E.C.A., Szulejko, J.E. and McMahon, T.B. (1991). Strong hydrogen bonding in gas-phase ions. A high-pressure mass spectrometric study of the proton affinity, proton transfer kinetics, and hydrogen-bonding capability of iron pentacarbonyl. *Journal of the American Chemical Society*, **113**, 4469–4473.

Ingemann, S., Kluft, E., Nibbering, N.M.M., **Allison, C.E.**, Derrick, P.J. and Hammerum, S. (1991). Time-dependence of the isotope effects in the unimolecular dissociation of tertiary amine molecular ions. *Organic Mass Spectrometry*, **26**(10), 875–881.

Stringer, M.B., Underwood, D.J., Bowie, J.H., **Allison, C.E.**, Donchi, K.F. and Derrick, P.J. (1992). Is the McLafferty rearrangement of ketones concerted or stepwise? The application of kinetic isotope effects. *Organic Mass Spectrometry*, **27**(3), 270–276.

Ayers, G.P. (1990). Tropical atmospheric acidity: what now and where to? In B.N. Noller and M.S. Chadha (editors.), *Chemistry and the environment: proceedings of regional symposium*. Brisbane. p. 121–132. London: Commonwealth Science Council.

Ayers, G.P. and **Gillett, R.W.** (1990). Tropospheric chemical composition: an overview of experimental methods in measurement. *Reviews of Geophysics*, **28**(3), 297–314.

Ayers, G.P. and Larson, T.V. (1990). Numerical study of droplet size dependent chemistry in oceanic, wintertime stratus cloud at southern mid-latitudes. *Journal of Atmospheric Chemistry*, **11**(1–2), 143–167.

Wilson, S.R. and **Ayers, G.P.** (editors). (1990). *Baseline Atmospheric Program (Australia)*(1988). [Canberra, A.C.T.]: Department of Administrative Services, Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research.

Ivey, J.P., **Ayers, G.P.** and McLean, T. (1990). Dimethylsulfide. In *Baseline Atmospheric Program (Australia)*(1988). p. 49. [Canberra, A.C.T.]: Department of Science, Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research.

Ayers, G.P. (1991). The International Global Atmospheric Chemistry Project's debit activity: a summary. *Clean Air*, **25**(1), 6–7.

Ayers, G.P. and **Bentley, S.T.** (1991). Meteorological perspectives on site selection for a rain-water composition study in the Latrobe Valley. *Australian Meteorological Magazine*, **39**(2), 95–103.

Ayers, G.P. and **Gillett, R.W.** (1991). Quadrupod aerosol sampler. In S.R. Wilson and J.L. Gras (editors.), *Baseline Atmospheric Program (Australia)*(1989). p. 57–58. [Canberra, A.C.T.]: Department of the Arts, Sport, the Environment, Tourism and Territories, Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research.

Ayers, G.P. and **Gras, J.L.** (1991). Seasonal relationship between cloud condensation nuclei and aerosol methanesulphonate in marine air. *Nature*, **353**(6347), 834–835.

Ayers, G.P. and Manton, M.J. (1991). Rainwater composition at two BAPMoN regional stations in SE Australia. *Tellus*, **43B**(5), 379–389.

Ayers, G.P., Ivey, J.P. and **Gillett, R.W.** (1991). Coherence between seasonal cycles of dimethyl sulphide, methanesulphonate and sulphate in marine air. *Nature*, **349**(6308), 404–406.

Ivey, J., **Ayers, G.P.** and Kittler, P. (1991). Dimethylsulfide in baseline air. In S.R. Wilson and J.L. Gras (editors.), *Baseline Atmospheric Program (Australia)*(1989). p. 56. [Canberra, A.C.T.]: Department of the Arts, Sport, the Environment, Tourism and Territories, Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research.

Ivey, J., **Ayers, G.P.** and Kittler, P. (1991). High volume sampler. In S.R. Wilson and J.L. Gras (editors.), *Baseline Atmospheric Program (Australia)*(1989). p. 55–56. [Canberra, A.C.T.]: Department of the Arts, Sport, the Environment, Tourism and Territories, Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research.

Baines, P.G. (1990). Introduction [Oceanic hydraulics]. *Pure and Applied Geophysics*, **133**(4), 571–572.

Baines, P.G. and **Granek, J.** (1990). Hydraulic models of deep stratified flows over topography. In L.J. Pratt (editor.), *The physical oceanography of sea straits*. p. 245–269. Dordrecht: Kluwer.

Baines, P.G. and Palmer, T.N. (1990). *Rationale for a new physically-based parameterization of subgridscale orographic effects*. (European Centre for Medium-Range Weather Forecasts. Research Department. Technical memorandum 169). [Reading, Eng.]: ECMWF.

Baines, P.G., Hubbert, G. and Power, S. (1991). Fluid transport through Bass Strait. *Continental Shelf Research*, **11**(3), 269–293.

Baines, P.G., Mitsudera, H. and **Murray, D.L.** (1991). *Aspects of ocean behaviour relevant to climate change: theoretical and laboratory studies of the dynamics of coastal currents: first interim report*. [Aspendale]: CSIRO Division of Atmospheric Research.

Baines, P.G., Mitsudera, H. and **Murray, D.L.** (1992). *Aspects of ocean behaviour relevant to climate change: theoretical and laboratory studies of the dynamics of coastal currents: second interim report*. [Aspendale]: CSIRO Division of Atmospheric Research.

Divisional authors are shown in bold typeface. This list does not include the following types of publications: abstracts of conference papers, book reviews, Divisional information sheets and internal or non-technical Divisional reports.

Barton, I.J. (1991). Infrared continuum water vapor absorption coefficients derived from satellite data. *Applied Optics*, **30**(21), 2929–2934.

Barton, I.J. (1991). Passive remote sensing instrumentation. In D. De Vries (editor.), *Proceedings of the fifth UN/FAO/WMO/ESA training course on the use of remote sensing in hydrological and agrometeorological applications*. Canberra. (COSSA publication 026). p. 63–69. [Canberra]: CSIRO Office of Space Science and Applications.

Barton, I.J. and Forgan, B. (1991). Measurements and climatic effect of the Mt. Pinatubo volcanic eruption: report of a joint CSIRO–Bureau of Meteorology workshop. *Clean Air*, **25**(4), 139–140.

Coppin, P.A., Bradley, E.F., **Barton, I.J.** and Godfrey, J.S. (1991). Simultaneous observations of sea-surface temperature in the western equatorial Pacific Ocean by bulk, radiative and satellite methods. *Journal of geophysical research*, **96**(Supplement), 3401–3409.

Barton, I.J. (1992). Satellite-derived sea surface temperatures: a comparison between operational, theoretical, and experimental algorithms. *Journal of Applied Meteorology*, **31**(5), 433–442.

Barton, I.J., Prata, A.J., Watterson, I.G. and **Young, S.A.** (1992). Identification of the Mount Hudson volcanic cloud over SE Australia. *Geophysical Research Letters*, **19**(12), 1211–1214.

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Beer, T. (1990). The Australian National Bushfire Model Project. *Mathematical and Computer Modelling*, **13**(12), 49–56.

Beer, T. and **Enting, I.G.** (1990). Fire spread and percolation modelling. *Mathematical and Computer Modelling*, **13**(11), 77–96.

Beer, T. (1991). Algorithms for calculating soil dryness index (SDI). In *Conference on Agricultural Meteorology: extended abstracts*. Melbourne. p. 290–292. Melbourne: Bureau of Meteorology.

Beer, T. (1991). *Applied Environmetrics hydrological tables*. Balwyn, Vic.: Applied Environmetrics.

Beer, T. (1991). Bushfire rate-of-speed forecasting: deterministic and statistical approaches to fire modelling. *Journal of Forecasting*, **10**, 301–317.

Beer, T. (1991). Bushfire-control decision support systems. *Environment International*, **17**, 101–110.

Beer, T. (1991). Comment on "On the fractal interpretation of the mainstream length-drainage area relationship" by A. Robert and A. G. Roy. *Water Resources Research*, **27**(9), 2487–2488.

Beer, T. (1991). [Editorial] Environmetrics. *Environment International*, **17**, 505–506.

Beer, T. (1991). [Editorial] Wildfires. *Environment International*, **17**, 99.

Beer, T. (1991). The interaction of wind and fire. *Boundary-layer Meteorology*, **54**(3), 287–308.

Beer, T. (1991). Modern developments in fire modeling and decision-support systems. In T.C. Daniel and I.S. Ferguson (editors.), *Proceedings of the U.S.–Australia workshop integrating research on hazards in fire-prone environments*. Melbourne, Australia. p. 46–52. [Washington, D.C.]: United States Man and the Biosphere Program.

Beer, T., Dawson, M.D., Moore, P. and Ryan, C. (1991). Remote weather stations: a survey. *Clean Air*, **25**(2), 54–59.

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Boers, R., Melfi, S.H. and Palm, S.P. (1991). Cold-air outbreak during GALE: lidar observations and modeling of boundary layer dynamics. *Monthly Weather Review*, **119**(5), 1132–1150.

Borgas, M.S. (1991). The multifractal nature of turbulent dispersion. In A. V. Johansson and P.H. Alfredsson (editors.), *Advances in turbulence III: proceedings of the Third European Turbulence Conference*. Stockholm. p. 125–132. Berlin: Springer-Verlag.

Borgas, M.S. and **Sawford, B.L.** (1991). The small-scale structure of acceleration correlations and its role in the statistical theory of turbulent dispersion. *Journal of Fluid Mechanics*, **228**, 295–320.

Bouma, W.J. (1990). Global warming: countering the critics. ([CSIRO/DAR Information paper]). Aspendale, Vic.: CSIRO Division of Atmospheric Research.

Bouma, W.J. (1990). DAR's position on targets for reducing greenhouse gas emissions. ([CSIRO/DAR Information paper]). Aspendale, Vic.: CSIRO Division of Atmospheric Research.

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Bouma, W.J. (1990). The greenhouse effect. *SAE–Australasia*, **50**(6), 33–37.

Bouma, W.J. and **Holper, P.N.** (1990). *Climate change: the effect of increased carbon dioxide and other greenhouse gases in the global atmosphere: a bibliography of scientific publications from the CSIRO Division of Atmospheric Research 1971–1989.* [Aspendale, Vic.]: [CSIRO Division of Atmospheric Research].

Bouma, W.J. and **Holper, P.N.** (1990). *Depletion of stratospheric ozone: stratospheric ozone: observations and dynamics; ozone depleting substances in the global atmosphere: a bibliography of scientific publications from the CSIRO Division of Atmospheric Research 1971–1989.* [Aspendale, Vic.]: [CSIRO Division of Atmospheric Research].

Bouma, W.J. (1991). The climate effect of burning oil-fields in the Middle East. ([CSIRO/DAR Information paper]). Aspendale, Vic.: CSIRO Division of Atmospheric Research.

Bouma, W.J. (1991). *Oil fires in the Gulf: possible effects on climate.* (CSIRO/DAR Information paper 91/3). Aspendale, Vic.: CSIRO Division of Atmospheric Research.

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Cai, W. (1992). A revised layered model: application to the Bonney coast upwelling. *Estuarine, Coastal and Shelf Science*, **34**(3), 235–252.

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