

CSIRO
DIVISION OF ATMOSPHERIC RESEARCH



RESEARCH REPORT 1988 - 1990

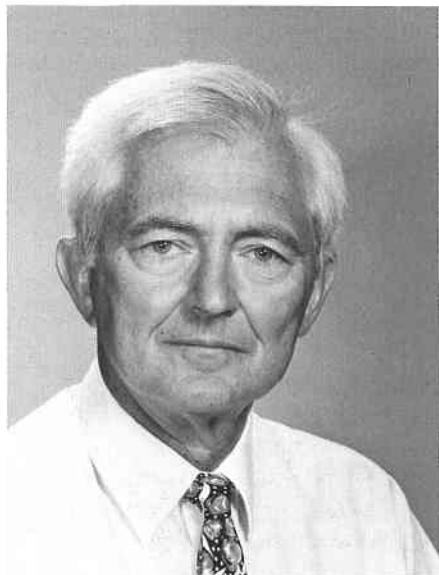
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FOREWORD



Dr G.B. Tucker

Environmental issues continue to occupy centre stage in matters of public concern. Passionately held beliefs and alignments have characterized debates on the environment and the economy, and on conservation and development. These topics evoke strong emotions, and confrontationist arguments from both sides often confuse the issue by hyperbole and extravagant rhetoric. It is all the more important, therefore, for sound objective scientific assessment both of the physical problems and of the arguments of protagonists to be available to the general public and to policy makers. The Chief Executive of CSIRO, Dr John Stocker, has recently referred to the role of CSIRO as being "an honest broker" in such matters.

In this report of research progress at the CSIRO Division of Atmospheric Research, the role of atmospheric scientists in making such assessments is clear. We are fortunate in being able to combine objective environmental appraisals with strong scientific progress in each of our four research Programs: Global Atmospheric Change, Atmospheric Pollution, Remote Sensing, and Water Resources. Significant achievements in selected problems associated with weather, climate and atmospheric

pollution have been possible because of disciplinary skills and knowledge resident at the Division, some of which have been built up over past decades. The relevance and effective application of this expertise to national problems is attested by the research grants and external funding listed in our financial statement. We have been careful to undertake these studies without compromising the strategic component of our research which is the font for future applications.

At the same time, however, it is part of our ongoing plan to persuade authorities which are not yet disposed to make full use of skills and achievements to use us rather than to divert precious resources to setting up research programs of their own. The Division already has strong links with State and Commonwealth Government Departments and with various tertiary institutions. It also maintains an active program of international scientific collaboration.

Climate research being undertaken at the Division is now substantial by world standards. All four of our formal Programs contribute to this topic. We have been able to make strong advances on several fronts by combining the expertise of atmospheric chemists, scientists concerned with physical processes, and general circulation modellers. A Climate Research Laboratory was constructed recently to allow many of those who specialize in these areas to work in proximity to each other. The laboratory was opened in March 1990 by the Prime Minister, The Right Honourable R.J. Hawke. This was the first Prime Ministerial visit to the Aspendale site in the Division's history.

It is a pleasure to acknowledge a sense of community within the Division, a sense of pride in past achievements, an obvious enjoyment of internal and external interactions and a real commitment to the challenge of the future.

G.B. Tucker
Chief of Division

INTRODUCTION

The Organisation

CSIRO was established in 1926. Its main concern was research for agriculture and primary industry. As the organisation developed it began catering to secondary industries and in 1949 was charged with undertaking strategic research on behalf of all industries in Australia.

About 2500 scientists are employed by CSIRO. The major objectives of the Organisation are to:

- carry out strategic research that can be applied by Australian industry or Government for community benefit
- collaborate with other institutions and industry to strengthen the research effort and ensure its transfer and application
- lead and promote an expanded science and technology effort in Australia

The Institute

Research is performed in 35 Divisions and Research Units. The Division of Atmospheric Research is part of the Institute of Natural Resources and Environment. The Institute aims to provide the scientific knowledge required for the effective management and conservation of Australia's natural resources and environment, particularly in relation to the conservation and protection of natural heritage and sustainable use by dependent industries.

The Division

Research at the Division is aimed at improving our understanding of the physics, dynamics and chemistry of the atmosphere of both the Australian region and the globe. Investigations focus on studies of weather and climate, and atmospheric pollution. The Division seeks to provide the best possible advice on practical problems which are relevant to community concerns and to industry.

The Division has a staff of approximately 150, including 90 scientists and 60 support staff.

Scientific activities are carried out within four research programs:

- Global Atmospheric Change
- Atmospheric Pollution
- Remote Sensing
- Water Resources

The Divisional Advisory Committee

Since its inception in 1984, the Divisional Advisory Committee has given invaluable advice to the Chief on policy and other matters. The aim of the Committee is to assist the Division in its ongoing efforts to achieve appropriate, viable research directions which respond to the needs of the Australian community.

Chairman

Mr A.F. Rainbird
Deputy Chief Executive
Civil Aviation Authority

Mr R.P. Llewelyn (Retiring member)
Former Manager, Research and Development
State Electricity Commission of Victoria

Dr I.R. McPhail
Director-General
Department of Environment and Planning
South Australia

Mr T. Silverson
Former Executive Director
ICI Australia Ltd

Dr G.B. Tucker
Chief
Division of Atmospheric Research

Secretary to the Committee
Dr W.J. Bouma
Scientific Assistant to the Chief
Division of Atmospheric Research

Opening of the Climate Research Laboratory

"I am delighted to be here at the CSIRO Division of Atmospheric Research to inspect your research work on the changes taking place in the regional and global atmosphere ... It is vitally important work, for there is no greater global environmental concern than the greenhouse effect and the depletion of the ozone layer ... The CSIRO enjoys a fine reputation for outstanding research and development work. Your research program here is a credit to all of you."

This is an extract from the speech by the Prime Minister, The Right Honourable R.J. Hawke, at the opening of the Climate Research Laboratory at the Division on 19 March 1990. Also present were the Minister for Science, Mr Barry Jones, the Minister for Environment, Senator Graham Richardson, and the new Chief Executive of the CSIRO, Dr John Stocker.

Following the opening, Mr and Mrs Hawke and the official party were shown the new building after which they visited the Geophysical Fluid Dynamics Laboratory for a demonstration of water-tank experiments which simulate real-life atmospheric pollution problems.

The Climate Research Laboratory is used for climate change modelling which involves calculating the effects of greenhouse gas emissions on factors such as rainfall, cloudiness, sea level and atmospheric temperature. Climate model results and other information are being used to establish the likely regional impacts of the greenhouse effect. The Division is currently investigating how a number of states and territories are likely to be affected.

The new 1200 square metre building, which contains some 60 offices and workrooms as well as a new committee room, was completed on schedule and within budget.



The Prime Minister, The Right Honourable R.J. Hawke, opening the Division's new Climate Research Laboratory. Seated (from left) are Mr Barry Jones, Senator Graham Richardson, Dr Brian Tucker and Mrs Hazel Hawke.

GLOBAL ATMOSPHERIC CHANGE



Program Leader
Dr Graeme Pearman

Human activities are increasing the atmospheric concentrations of certain greenhouse gases, including carbon dioxide, methane, nitrous oxide and chlorofluorocarbons. This is likely to upset the solar-terrestrial radiation balance, leading to global warming and consequent changes in climate.

For many years the Division has been monitoring the chemical composition of the atmosphere. This has led to advances in understanding of sources, transport, distribution, and sinks of important trace gas species and particles. Such knowledge is essential for predicting future change and for assessing the likely impacts of strategies to limit emissions.

The way in which Australia is likely to be affected by climate change is of vital interest. The main emphasis of research is on the construction and development of computer general circulation models. These models synthesize the atmospheric, terrestrial and oceanic processes which contribute to climate. A range of information, including model results and historical data, is being used to assess the likely impact of climate change on a regional basis.

Greenhouse gases

The Division is currently upgrading its gas-measuring equipment. Substantial improvements in precision, sensitivity and efficiency will provide access to important new information about the composition of our atmosphere.

The Global Atmospheric Sampling Laboratory (GASLAB) has been created to house new instruments. A Finnigan-MAT 252 mass spectrometer and new gas chromatographs will expand the range of gas species able to be measured. A centralized computer will control the measurement sequences, process and archive data, and provide comprehensive quality control and analysis.

Projects

- The mechanisms and causes of increases in non-reactive gases (carbon dioxide, methane and chlorofluorocarbons) in the global atmosphere
- Scientific support for the Cape Grim Baseline Atmospheric Pollution Station
- Chemical, physical and biological mechanisms regulating reactive gases and aerosols in the global atmosphere
- General circulation studies of the dynamics and physics of global and regional atmospheric change
- Regional climate change estimates and impact assessment
- Ocean/Atmosphere modelling relevant to climate change and prediction
- Biospheric inputs to atmospheric general circulation and climate prediction models



Air samples collected since 1978 are providing detailed information about the changing composition of the world's atmosphere

The new laboratory is being funded in part by the Department of Arts, Sports, the Environment, Tourism and Territories (DASETT).

The carbon cycle

Carbon dioxide is currently responsible for more than half of the likely increase in global warming associated with the release of greenhouse gases into the atmosphere. Recent research has shown that the oceans may be taking up less carbon dioxide than previously supposed. This suggests that elements of the biosphere on the continents, such as trees, grassland and crops may be absorbing and sequestering more of this gas.

The impact of plants on the concentration of carbon dioxide is a topic of great interest. World-wide clearing of forests adds to the amount in the

atmosphere, while re-growth and enhanced plant productivity in a carbon dioxide-rich atmosphere can result in absorption. If recent ocean uptake estimates are correct, the role of plants is the most uncertain part of the atmospheric carbon budget. Model development and new measurement programs should help clarify this issue.

The cycle and global budgets of carbon and other radiatively active gases are explored using a hierarchy of computer models. One-dimensional models are used for studies of global features on decadal to century timescales, two-dimensional models for surface exchange and seasonal behaviour, and three-dimensional models for detailed transport and exchange processes.

Antarctic ice cores

An accurate determination of the past concentrations and exchanges of greenhouse gases is a key factor in understanding their current budgets. It will also help evaluate the contribution of the gases to current greenhouse warming. The Australian Antarctic Division's ice-core drilling program provides Divisional scientists with access to samples of air trapped during the past millenia in Antarctic ice.

A significant ice core, containing air which spans the last 150 years, is being examined. The spread of ages of the air is only eight years and the mean age is determined within one year. Precise measurements of oxygen and carbon will shed light on details of the

carbon budget and should also indicate the relative importance of the oceans and the biosphere as sinks for carbon dioxide over the century timescale.

Techniques are also being developed to investigate tropospheric ozone chemistry. This would provide information on the way in which the chemistry of the atmosphere has changed since the industrial revolution. The establishment of the ICELAB (Ice Core Extraction Laboratory) at the Division will benefit this work.

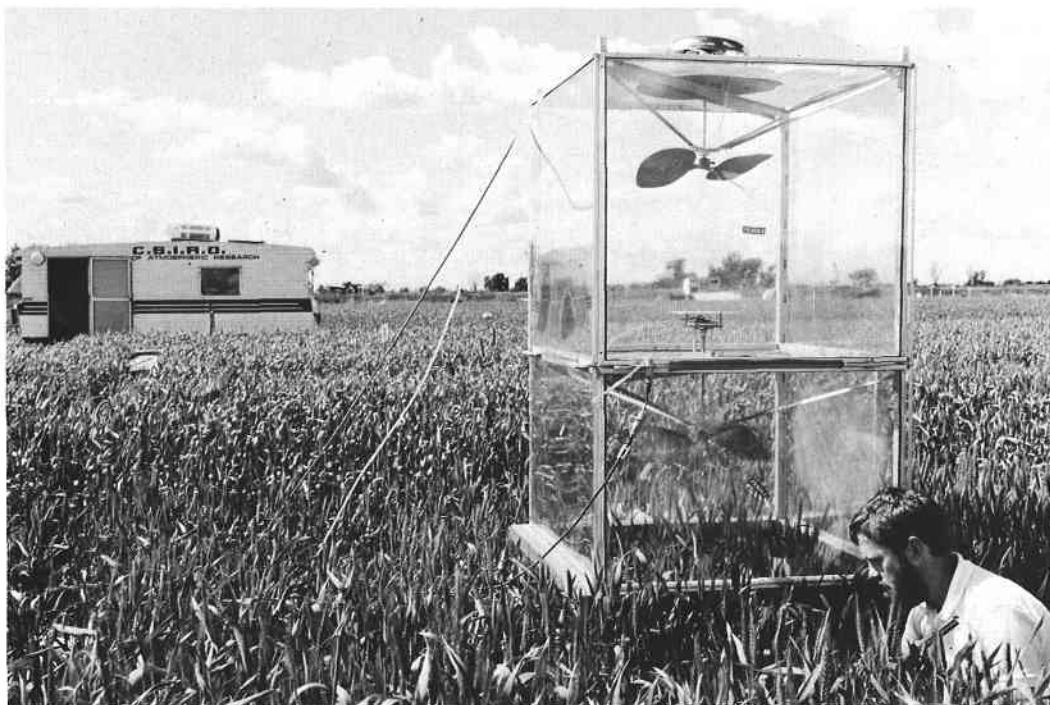
Cape Grim Baseline Air Pollution Station

It is now over 20 years since the World Meteorological Organisation (WMO) saw the need for a global network of stations to monitor long-term trends in atmospheric composition. Australia's contribution to this network was established at Cape Grim, in north-western Tasmania, in 1976. This station, jointly managed by the Bureau of Meteorology and CSIRO, plays a vital role in evaluating the impact of human activities on the global atmosphere.

Cape Grim is an important part of the global network as it is one of the few monitoring stations in the southern hemisphere and one of the most sophisticated in the world. Measurements of greenhouse gases provide valuable information for assessing the likely nature and extent of future greenhouse-induced climate change. Carbon and other isotope ratios assist the identification of the sources and sinks of these greenhouse gases.



The Cape Grim Baseline Air Pollution Station



Emissions of gases from crops are being studied using specially constructed chambers

In addition to being greenhouse gases, chlorofluorocarbons have been implicated in depletion of stratospheric ozone. The measured increase in concentrations of these gases in the atmosphere has provided vital information for the Montreal Protocol. The Protocol, which has recently been revised, is an international agreement designed to limit the production of ozone-depleting chemicals.

Various particles are known to act as nuclei upon which water droplets can form in clouds. Dimethyl sulfide, produced by decomposing sea plants, is a significant source of naturally occurring atmospheric sulfur. The number of sulfur-containing particles above the oceans strongly influences the persistence of clouds, the reflection of radiation and the likelihood of rain. Instruments at Cape Grim have been used for some time to provide data on dimethyl sulfide concentration and aerosol particles.

Extensive international collaborative work is performed at the station. Activities, data and research results at Cape Grim represent Australia's main contribution to the United Nations WMO Background Air Pollution Monitoring Network.

Oxides of nitrogen

Microbial processes play a major role in cycling compounds through the atmosphere. Nitric oxide (NO), a gas associated with regional air pollution, is produced by both nitrifying and denitrifying microbes. The first measurement of nitric oxide release from soils was made by Divisional scientists more than ten years ago. However, until now it has been difficult relating laboratory measurements to those obtained in the field.

Flow-through soil columns have commonly been used for investigating the release and uptake of gases. The Division has successfully devised an empirical kinetic model to represent the bulk production and uptake of nitric oxide within soil. Under certain specified conditions, column data for a specific type of soil can be used to determine the field flux.

Wheat field studies

In order to maintain protein levels, large quantities of fertilizer nitrogen are applied to irrigated wheat. However, much of this fertilizer — an expensive commodity — may never be taken up by the crop. In fact, it has been shown that more than half of the nitrogen may rapidly enter the atmosphere.

The Goulburn Valley in northern Victoria was used as the site for a detailed study of gas fluxes. Measurements of nitric oxide emissions were made at crop height in a chamber constructed from an aluminium frame surrounded by transparent plastic sheeting.

Emissions from fertilized wheat fields were up to ten times greater than those from unfertilized fields. Soil processes represent the major source of nitric oxide lost to the atmosphere. Even after the wheat had been harvested, significant quantities of nitrogen were still being released from the bare soil.

General circulation modelling

A concerted effort is being made to improve our knowledge of the way in which global and regional climate is likely to respond to increasing concentrations of greenhouse gases. The general

circulation models used for this research are continually being refined. For studies of specific regions, atmospheric limited-area models are being developed. The interaction between oceans and the atmosphere has a significant impact on climate; hence the importance of coupling ocean and atmospheric models.

In order to model the complexity of the atmosphere, a great deal of computer power is needed. Considerable attention has been given to increasing the speed of the models, both on the Cyber 205 computer and on the new CRAY Y/MP supercomputer.

The Division's four-level model is being extended to nine vertical levels. Preliminary experiments are well under way in establishing the model's climatology, and results so far are encouraging.

The first greenhouse experiment, using the Division's four-level model coupled to a simple ocean, has been completed. This experiment incorporated doubled atmospheric carbon dioxide concentrations. Results indicate considerable changes to the world's temperature patterns. Under greenhouse conditions, the model suggests major warming especially in arid regions such as Western Australia. The model continues to show large year-to-year variability, so that individual cool years still occur despite the average warming.

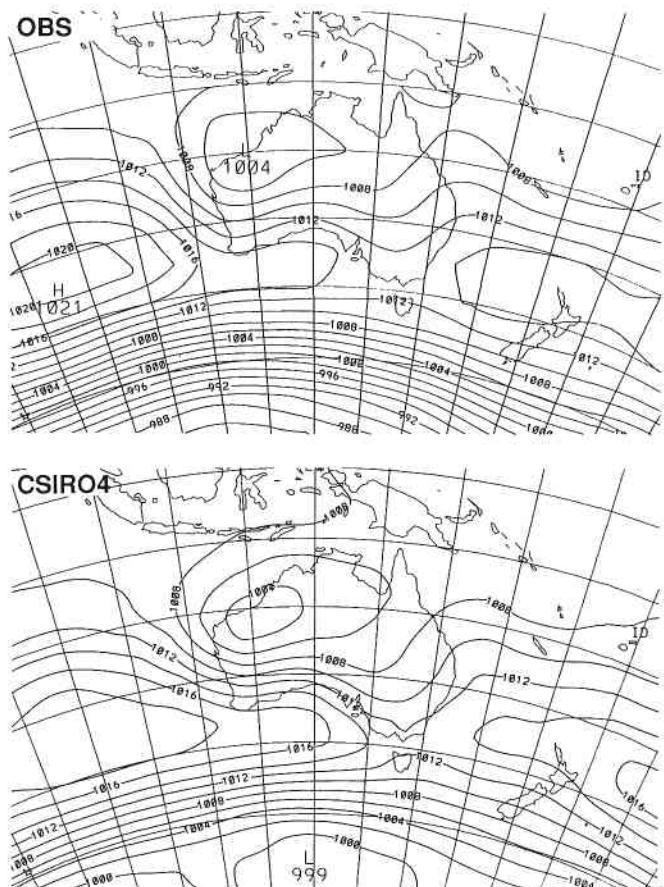
An intense effort is now underway to improve the ocean component of this climate model, and to improve the way in which clouds, land surface processes and air-sea interactions are incorporated.

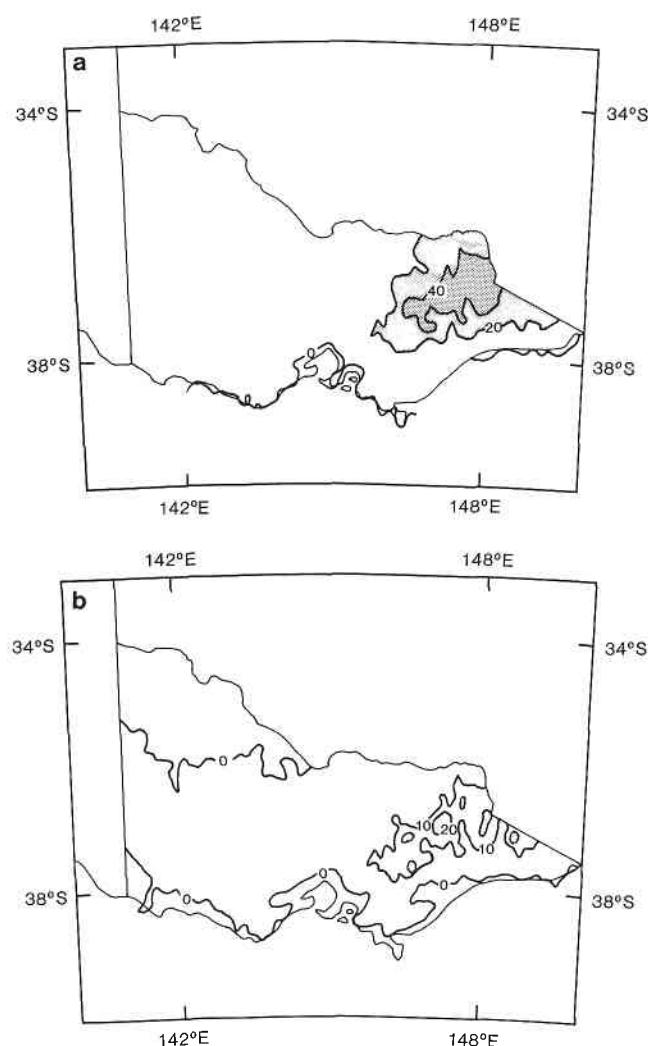
Limited-area modelling

Global circulation models have a horizontal resolution of approximately 500 km, whereas local-precipitation and soil-moisture patterns are often related to small-scale features. Running a global model at high horizontal resolution is prohibitively expensive. An attractive alternative is to carry out a full global greenhouse simulation at the usual resolution and then nest a higher-resolution mesoscale model within it, so that the global model is essentially supplying the broad climatology. A limited-area model has been developed with an extensive set of physical parameterizations. Encouraging results have been obtained from a number of 120-day integrations using a 250 km grid. Extended higher-resolution (50 km grid) simulations are planned.

Land surface modelling

The Division is using its experience in boundary-layer and land-surface physics to improve the representation of the surface and atmospheric boundary layer in general circulation models. In order to take properly into account land surface comprising vegetation or soil, a soil-canopy scheme needs to be





Contours of average number of days in winter when daily minimum temperatures are less than or equal to 0°C, before (above), and after (below), a 3°C uniform greenhouse warming

between the atmosphere and the oceans, and thus, to a large extent, the energy available to drive the atmosphere. Furthermore, the thermal capacity of the oceans and the fact that they act as a sink for carbon dioxide will delay the warming anticipated as a result of the greenhouse effect.

Experiments have been performed with an ocean model obtained from the Geophysical Fluid Dynamics Laboratory, Princeton. Realistic ocean-floor topography and increased horizontal resolution have been added. This has improved the representation of surface, coastal and equatorial currents. Ultimately, a twelve-level version of the ocean model will be coupled to the Division's atmospheric model.

The impact of climate change

Divisional scientists are aiming to provide the best available estimates of the likely Australian regional climatic changes and impacts of the greenhouse effect.

Information is being obtained from a variety of sources. Local and overseas climate models for the Australian region are being used. Limited-area models are being modified to simulate specific meteorological phenomena such as tropical cyclones and cold fronts. The models will then be used to study sensitivity of such phenomena to changes in large-scale climate. The historical data record, fossil records, and physical arguments are also important. It must be realized that none of these methods is perfect and there will continue to be uncertainties. The objective is to narrow these uncertainties, weigh the balance of evidence, and provide the best available advice.

Model results

In order to assess the impact of increased levels of greenhouse gases, results from general circulation models incorporating doubled carbon dioxide concentrations are compared with those using current concentrations. A number of overseas and local models have been analysed.

One of the necessary conditions for having confidence in model greenhouse simulations is that they satisfactorily represent current Australian climate in control runs. Of the various general circulation model simulation results available in computer-compatible form, only the CSIRO and the United Kingdom Meteorological Office models gave acceptable results. Other, more recent simulations may well be better.

All greenhouse simulations show surface temperature warming of about 2°C to 5°C averaged over all Australian grid points. Greater warming occurs inland and in the drier parts of the continent and less along the coast, but there is little agreement between the predicted rainfall changes. The Division's model, which performed well in its control run over Australia, indicates an increase of approximately 10% in summer rainfall in northern and eastern Australia. Conversely, it shows a decrease in winter rainfall of between 10% and 20% in the south-west of the country. These changes correspond to a generally southward shift of the high pressure belt in both January and July over Australia.

It must be stressed that these are preliminary results. Soil moisture and run-off depend on both rainfall and evaporation and the latter has not yet been examined. In general, a 3°C to 4°C warming would result in a 10% to 15% increase in evaporation. However, there could be significant local variations associated with topography and other factors.

Analysis of historical data

The impact on Victoria of a uniform 3°C warming has been analysed. Warming of this magnitude would have important implications for agriculture, fire frequency and winter snow accumulation. In many parts of the



Thermal expansion of the oceans and melting of land-based ice contribute to rising sea levels

state, the number of days in which maximum temperatures are at least 35°C would double.

Certain crops, such as apples, nuts and stone fruits require winter chill conditions or "vernalisation". Under warmer conditions, the number of cold days necessary for these crops to fruit will drop and the viability of production in certain areas may disappear.

It must be stressed that this initial analysis, supported by the Victorian Government's Greenhouse Program, is based on a number of crude assumptions and simply provides a guide to a number of possible impacts.

Sea-level rise and the Australian coastline

A national workshop on the greenhouse effect, sea-level rise and the Australian coastline was held at the Division in 1989. The principal conclusion was

that the expected rise in global average sea level by the middle of next century will be between 10 cm and 50 cm. At the regional and local level, there may be important differences in relative sea level due to a range of meteorological and oceanographic factors which may change due to global warming. These factors include storm surges, wave activity, and variations in coastal currents. Changes in the frequency, location and magnitude of extreme events, such as those associated with tropical cyclones and east-coast low pressure systems may have the greatest short-term effect on many coastal areas.

The climate change impact work is being supported by the Department of the Arts, Sport, the Environment, Tourism and Territories (DASETT), and by various state and territory governments.

ATMOSPHERIC POLLUTION



Program Leader
Dr. John Garratt

Atmospheric pollution occurs when substances are present at concentrations sufficiently above normal ambient levels to produce a measurable effect on humans, animals, plants or materials. These substances may come from natural or man-made sources and may exist as gases, liquids, or solid particles. The major man-made sources include transportation, power generation, burning of biomass, and industrial processes. Once released into the atmosphere, pollutants may then be transported, diluted, and physically and chemically transformed. The relationship between emission levels and airborne concentrations at different locations is an important area of interest.

The Atmospheric Pollution Program is studying the factors which influence air pollution and analysing impacts of specified pollutant sources. A variety of techniques are employed, including theoretical analysis, numerical model and laboratory experiments, as well as field measurements.

A number of urban and regional studies have recently been performed. Analysis of the hydrocarbon composition of air has been carried out in Melbourne's western suburbs. Power generating regions of Victoria, Queensland, New South Wales and Western Australia have been studied. Important collaborative work continues with colleagues overseas, while expertise built up at the Division has been applied to a specific air pollution project in Korea.

Dispersion of smoke plumes

Field studies

Our understanding of dispersion under convective conditions is improving rapidly through theoretical research and laboratory experiments. Convection in the atmosphere is the upward movement of air which has been heated by contact with the ground.

Until recently, there has been no field data which adequately cover parameters such as plume buoyancy

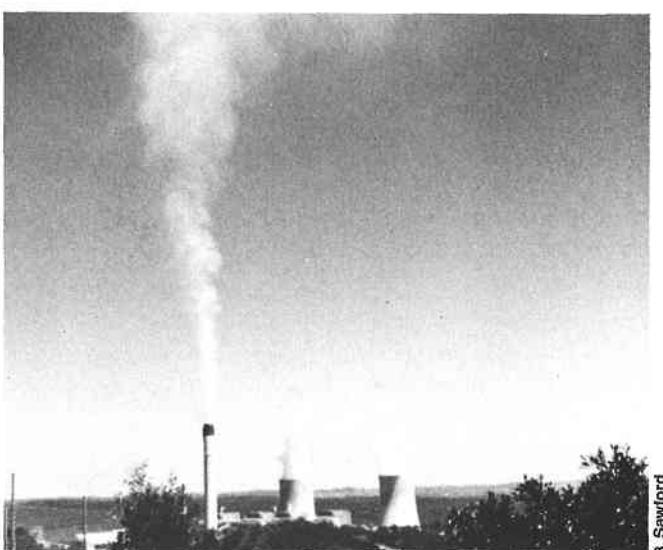
Projects

- Theoretical and experimental studies of turbulent dispersion in the atmospheric boundary layer
- Air quality dynamics: Research and applications
- Air quality and visibility studies
- Bushfire meteorology

flux, stack height, and atmospheric stability. In order to collect such data, a major plume-dispersion study funded by the National Energy Research, Development and Demonstration Council (NERDDC) was undertaken at Tarong power station in southern Queensland during 1988 and 1989. Tarong is a modern 1400 MW power station operated by the Queensland Electricity Commission (QEC).

Detailed measurements of emissions were made under a variety of convective conditions. Meteorological data, such as the depth of convection and the surface heat flux, defined the state of the convective boundary layer. Turbulence and wind-field measurements determined the influence of local terrain.

A variety of experimental techniques were used during this study. By scanning rapidly through a range of elevation angles at various azimuths, a lidar provided detailed measurements of plume concentrations. Turbulence and wind-field measurements were made with an acoustic radar, and radiosondes measured wind speed and direction, humidity, and temperature. Time-exposure photographs of the plume were taken from suitable vantage points. In addition to routine logging of stack gas temperature and flow rate, monitoring of NO_x and SO_2 was performed in the stack and downwind at ground level.



The Tarong Power Station

B. Sawford



The behaviour of smoke plumes in the atmosphere is studied in this 4000 litre modelling tank. Saline solutions are used to generate the buoyancy flux normally produced by heat.

The data set thus obtained is being used to improve atmospheric-dispersion prediction procedures under development within CSIRO and elsewhere. It will also facilitate calibration of laboratory facilities such as the Monash University Environmental Wind Tunnel.

This collaborative field study involved the CSIRO Division of Coal Technology and Centre for Environmental Mechanics, and scientists from the QEC, Queensland University of Technology, and Flinders University.

Laboratory and theoretical studies

The Division's new laboratory facility for studying plume dispersion in a convective boundary layer has been described in the 1985–1988 Research Report. Preliminary results from analysis of the effect of buoyancy on plume rise and dispersion are in good agreement with other laboratory data and the field data from the Tarong study. A program of quantitative dispersion measurements is due to start in July 1990.

Lagrangian stochastic models are being developed to study a range of dispersion processes. Models to predict the mean concentration field and dispersion in an absolute reference frame and the concentration variance and dispersion relative to the plume centre-of-mass are being studied. Work being undertaken ranges from fundamental research directed at improving the basis for these models, to the development of applications to specific atmospheric dispersion problems.

The choice of model formulation for a particular study and the ability of the model to accurately deal with a wide range of flows are areas of continued investigation. This fundamental work has led to a new understanding of Lagrangian acceleration statistics and their importance in developing soundly-based models.

On the more applied side, stochastic models for dispersion in the convective boundary layer have been developed. The Lagrangian stochastic approach has also been extended to model the dispersion of heavy particles such as dust and pollen, by including the effects of inertia and settling. This extended model provides a good representation of wind tunnel data on the dispersion of particles of this type.

Numerical modelling

Numerical modelling has been used in a number of regional air-quality studies to predict wind speed and direction at different heights and at high resolution. This method relies on simulations of atmospheric flow pattern developments from an initial observed state. In the model, particles are then transported by the winds and also allowed to diffuse according to turbulence theory.

A similar approach has been used to study morning fumigation events and associated ground-level concentrations within 30 km of stack emitters. Fumigation occurs when the shallow nocturnal inversion is replaced by a growing convective boundary layer as the morning sun heats the Earth's

surface. The layer grows to encompass the entire plume and turbulence can bring the plume to the ground. For a few hours, high smoke concentrations may occur at ground level close to the stack. Later in the day, the convective boundary layer grows higher and convection increases in intensity, thereby diluting the plume.

On-going research has resulted in improvements to model representation of ground-level concentrations of air pollutants. Such research can improve control strategies designed to significantly reduce pollution levels from emission sites.

Internal boundary layers

Internal boundary layers in the atmosphere are caused by the horizontal movement of air across a discontinuity in some property of the surface. This can occur when air flows across a coastline, where changes in surface temperature and roughness are prominent.

With on-shore flow, a convective thermal internal boundary layer grows inland from the coast. This can then have an impact on pollution from industrial sites located in the coastal region. During off-shore flow, the growth of the stable internal boundary layer over the sea is much smaller. Earlier work at the Division showed that this could influence the motion of summer-time cold fronts as they approach the coastline of south-eastern Australia.

A number of observational studies were carried out in the summer of 1984 and 1985 using the CSIRO F27 research aircraft. Flights over the sea to the south-west of Mt. Gambier demonstrated the dependence of internal boundary layer depth on several factors, including the amount of open water across which the wind is blowing, the strength of the wind itself, and the temperature difference between land and sea. The results were consistent with an earlier numerical study.

A major review of the internal boundary layer has been published, covering both small-scale and mesoscale aspects. Boundary layer response to a patchwork landscape, and the representation of surface heterogeneity in numerical models of the atmosphere are areas worthy of further study.

Mesoscale models often need to evaluate the depth of the boundary layer. Modifications to existing models to account for the growth of the thermal internal boundary layer in on-shore flow have improved the description of pollutant mixing. Such mixing was found to be particularly important when simulating numerically the impact of advected sea-breeze air on pollution transport in the Latrobe Valley.

Air quality analysis in Korea

A number of regional air quality studies have been completed, both in Australia and overseas. One such study, sponsored by the World Health Organisation, was conducted in Seoul, the capital of South Korea.

Air pollution is a major problem in this city and residents have made many complaints about specific sources of pollution. The Korean Ministry of the Environment recognised that proper source reviews would be necessary before it granted licences for the discharge of pollutants. Such reviews, which relate emissions to local air quality, involve mathematical models, the meteorology of the region, and background air quality. The model computes the expected local air pollution levels around the source allowing a judgment of the suitability of the proposed emitter for its particular locality.

The Division has advised the Ministry on air quality monitoring, and air pollution data evaluation; on the establishment of alarm systems for air pollution episodes; and on indoor air pollution standards. Underground shopping areas are a feature of Seoul and a declaration of air quality standards has recently been announced.



High-rise apartment buildings in Seoul, South Korea

Hydrocarbons in urban air

During the last decade, predictive models have been developed to simulate the transport and dispersion of power station emissions in the Melbourne area. A study of air composition was performed in, and close to, the western suburbs to provide data for verification of these models. Non-methanic hydrocarbon concentrations were measured at ground level and from an aircraft.

In order to monitor continuously concentrations at an unattended site, the Division has developed an

automatic, high-precision gas chromatograph which will operate for up to seven days at a time. It is self-calibrating and can monitor individual hydrocarbons of one to ten carbon atoms in composition.

The highest non-methanic hydrocarbon concentrations at Point Cook, 20 km to the south-west of Melbourne, occurred when winds were from the north-east. It is likely that these winds were carrying polluted air from the western suburbs. This supposition is supported by the fact that lowest concentrations were measured when winds blew from the south; an area with few hydrocarbon sources.

Not surprisingly, measurements taken in the western suburbs showed higher concentrations of hydrocarbons than at Point Cook. The proximity of the suburbs to industrial and motor vehicle sources accounts for this. The presence of lighter hydrocarbons (C_2 , C_3) in the air is consistent with the suggestion of emissions from industrial sources.

This work was performed under contract to the Victorian Environment Protection Authority (EPA).

Aerosols and visibility

One of the most noticeable effects of air pollution is reduction of visibility. This occurs because gas molecules and aerosols are able to both absorb and scatter light.

A pilot study of visibility-reducing particulate material during autumn and winter has commenced in Melbourne. Much of this material has been found to have a high carbon content, the majority of organic origin. Photochemical reactions, vehicle emissions, biomass burning and soil all contribute to the amount of fine particles in urban air. Nitrate was the main inorganic species contributing to light scattering. This



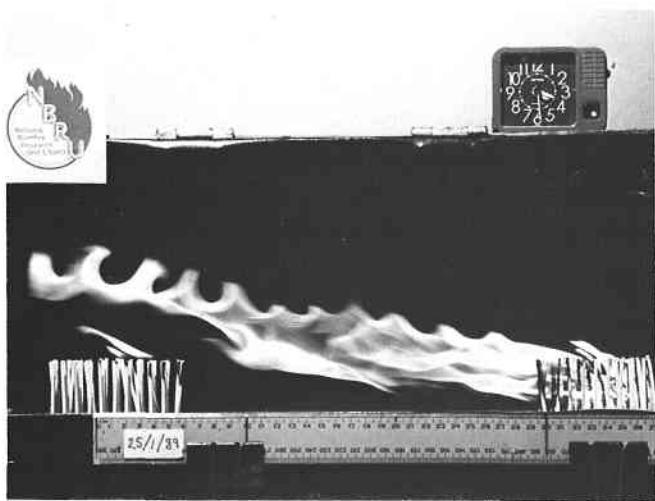
Monitoring urban air pollution. Air is drawn into the bag for subsequent analysis.

EPA-funded project involves both physical and chemical analysis as well as a study of sources of aerosols.

Bushfire meteorology

The development of a personal-computer-based fire-spread model which acts as a data assimilation tool is a project of high priority. Recent efforts aim to develop better mathematical sub-models to improve the overall model. The latest version of the National Bushfire Model was tested by the State Electricity Commission of Victoria in the Latrobe Valley during the 1989/90 bushfire season. The software performed well and during the coming year programs will be developed to access the latest topographic map databases.

It has been suggested that forest-fire spread can be modelled using percolation theory. This theory endeavours to explain the factors which determine whether or not movement will occur through a particular medium. Random arrays of burning matches were used to test this; the results showed that simple percolation theory does not predict the observed behaviour of fire-fronts in this experiment. Therefore, a more complex theory has been developed to explain laboratory results.



Arrays of matches in a wind tunnel are used to investigate fire propagation

REMOTE SENSING



Program Leader
Dr Martin Platt

Remote sensing is the acquisition of information by instruments remote from the phenomena under study. These instruments can be passive, receiving radiation from reflected sunlight or heat emissions from the ground. Alternatively, they can be active, measuring the scattering from clouds and aerosols of a transmitted light pulse.

Different materials absorb and reflect the sun's radiation in different ways. This enables passive detectors, mounted on satellites and aircraft, to obtain a great deal of information about the earth's surface, and the way in which radiation passes through and interacts with the atmosphere.

The Remote Sensing Program is applying its satellite research to a range of environmental and community concerns. It is developing new methods to improve our knowledge of atmospheric and surface properties. Collaborative design work on new satellite-mounted instruments, such as the along track scanning radiometer and the atmospheric pressure scanner, represents a tangible contribution to Australian and international space research.

The development and applications of ground-based active laser radar, or lidar, continues. Cloud and aerosol studies enhance our knowledge of climate and atmospheric pollution. Lidar is regularly used as part of joint studies with other Divisional Programs as well as in combination with satellite measurements.

From July 1990, this Program will be known as "Radiation and Climate".

Clouds and radiation

The influence of clouds on the amount of solar radiation reaching the earth's surface represents one of the greatest uncertainties in the prediction of climate and climate change. Clouds can reduce the amount of radiation by reflecting it back into space.

Projects

- Satellite data applications: Mechanisms regulating the surface radiation balance and climate
- Commercialization of CSIDA
- New instruments for meteorological satellites
- Determination of cloud and aerosol properties by remote sensing
- Science and applications of along track scanning radiometer (ATSR)
- Supply of satellite value-added products to outside customers

This results in cooling. Conversely, clouds are also able to absorb infrared radiation emitted from the ground. This causes warming. Overall, clouds keep our atmosphere cooler than it would otherwise be. Without them, the earth's average surface temperature would rise from 15°C to 30°C.

It is important to assess which type of cloud is likely to predominate as concentrations of greenhouse gases increase. High clouds would have a positive feedback, enhancing warming, while low clouds may slow down the warming rate.

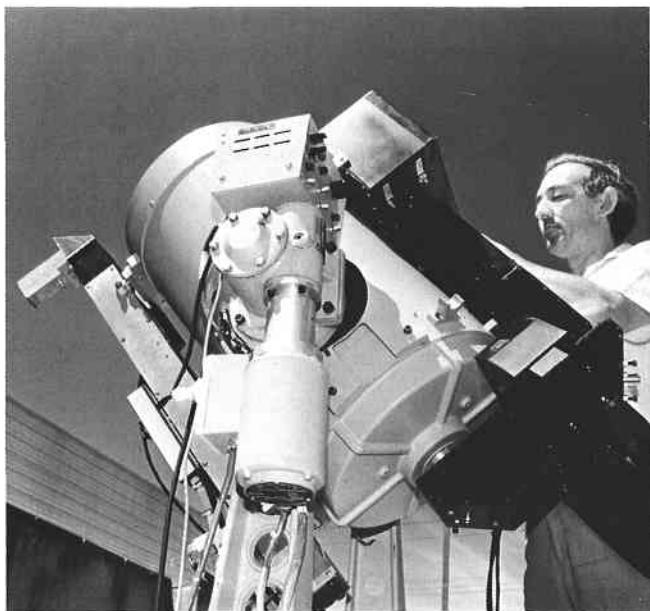
Tiny condensation nuclei in the atmosphere add to the uncertainty associated with climate change. Industrial smoke and pollution from other anthropogenic sources may be increasing the amount of these particles. This may lead to increased reflection of sunlight. Clearly, the impact on the earth's radiation balance of clouds and particles is a vital area of future research.

The investigation of cloud properties is being carried out by ground-based and satellite remote sensing techniques described below.

Lidar

The Experimental Cloud Lidar Pilot Study (ECLIPS) is an international observational program aiming to obtain information on cloud structure and the interaction of radiation with clouds.

Clouds at many different altitudes have been examined from the Division's site in Aspendale. Lidar and radiometers were used in conjunction with visible and infrared cloud images supplied by the CSIDA system. Observations were timed to coincide with satellite overpasses. The data collected will ultimately help elucidate the relationship between cloud properties and the amount of radiation received at ground level.



Aligning the Division's lidar for ground-based observations of clouds

The ECLIPS program is run jointly by the Division and NASA Langley Research Centre. A number of other laboratories from around the world are also taking part. The next intensive observational phase will be in May 1991.

The Global Backscatter Experiment (GLOBE) is designed to accurately determine atmospheric aerosol concentrations. In turn, these aerosol particles may be used to measure global wind from space. This would be achieved by using a satellite-mounted lidar to measure the frequency change of radiation reflected from the particles as they are carried by prevailing winds.

The Division collaborated with NASA scientists during the Melbourne stage of the first survey. The CSIRO F27 and the GLOBE DC-8 aircrafts were used to obtain atmospheric particle information at a range of altitudes. As a comparison, atmospheric profiles from ground level were made with lidar. This was a joint project between the Division's Global Atmospheric Change Group and the Remote Sensing Group.

Lidar's versatility has made it a valuable tool for a number of field studies. As part of the Tarong Power Station study (page 11), smoke plumes were scanned at various elevation angles. True plume characteristics are derived from raw data by algorithms which account for the loss of power or attenuation of the laser pulse as it passes through the smoke.

The instrument was also used during the Australian Winter Storms Experiment (page 21). Very dense, low cloud and mist often made measurements difficult, but the lidar accurately distinguished between water and ice clouds. It also supplied information on liquid water content and the size and concentration of droplets.

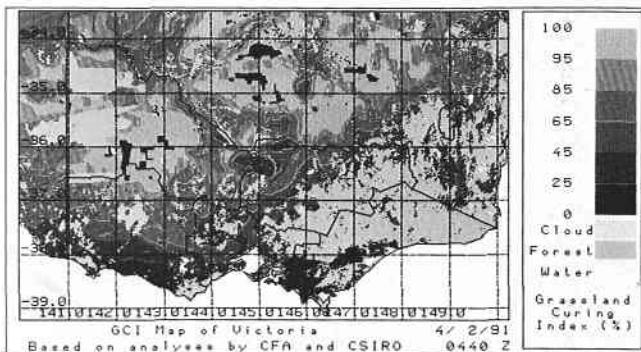
A new multi-purpose scanning lidar is presently being designed. This three-wavelength instrument, will be used for general purpose plume, boundary layer and cloud work. It will perform at high speed and will be able to deduce boundary-layer winds and temperatures in the upper atmosphere.

CSIDA

The CSIRO System for Interactive Data Analysis (CSIDA) was established primarily to provide satellite data and an interactive analysis system for Divisional Programs. It also provides data and various value-added products to primary industry, government agencies and tertiary institutions. Value-added products include normalized-difference vegetation indices for agricultural or fire-hazard applications, true-colour imagery for television weather presentation, and sea-surface temperature charts aimed primarily at the fishing industry. CSIDA has generated, and been involved with, a number of commercial ventures. A detailed description of the development of CSIDA and its previous activities can be found in the Division's 1983-1985 and 1985-1988 Research Reports.

CSIDA is currently being upgraded to operate on a networked configuration of Sun Unix workstations. Satellite data will feed directly into the network via a newly developed formatter card. Signal degradation due to cellular phone interference has been virtually eliminated by a new antenna feed. These, and additional planned improvements to the receiver, should enable the system to provide the data and manipulative power necessary for Divisional research activities requiring accurate interpretation of remotely-sensed data.

The quantitative application of satellite data depends on accurate calibration. A novel scheme has been devised to perform this routinely. In order to derive surface characteristics, corrections must be made for atmospheric scattering and absorption. Algorithms for this purpose are being developed and applied.



CSIDA-produced maps provide information to the Victorian Country Fire Authority on rural fire potential

Land surface temperature and frost risk

Frost is a major limiting factor to wheat production in southern Australia. As well as the direct damage to crops caused by frost, avoidance strategies can lead to substantial reductions in yields. It is important, therefore, to determine the earliest safe date for planting. Until now, farmers have had to rely on data which, in most regions, was determined from screen temperature measurements taken during the 1930s. There are considerable problems in relating such data to temperatures in the field. In addition, land-use changes have since occurred.

There is a real need for reliable, detailed and up-to-date data for determination of frost risk. This project aims to use satellite temperature data to determine the areas of greatest risk. In conjunction, a breeding and field-assessment program, operated by the Victorian Crops Research Institute, is determining the performance of short-season varieties of barley and wheat.

A small field site has been established in the Mallee in north-western Victoria. The Division is collecting and analysing temperature data from satellites using CSIDA and validating it at ground level. This provides valuable information about the relationship between satellite data and land-surface temperatures, and other parameters such as land forms, soils and vegetation types. It has also highlighted the variations between traditional screen temperature measurements, and the actual temperature experienced by the crop.

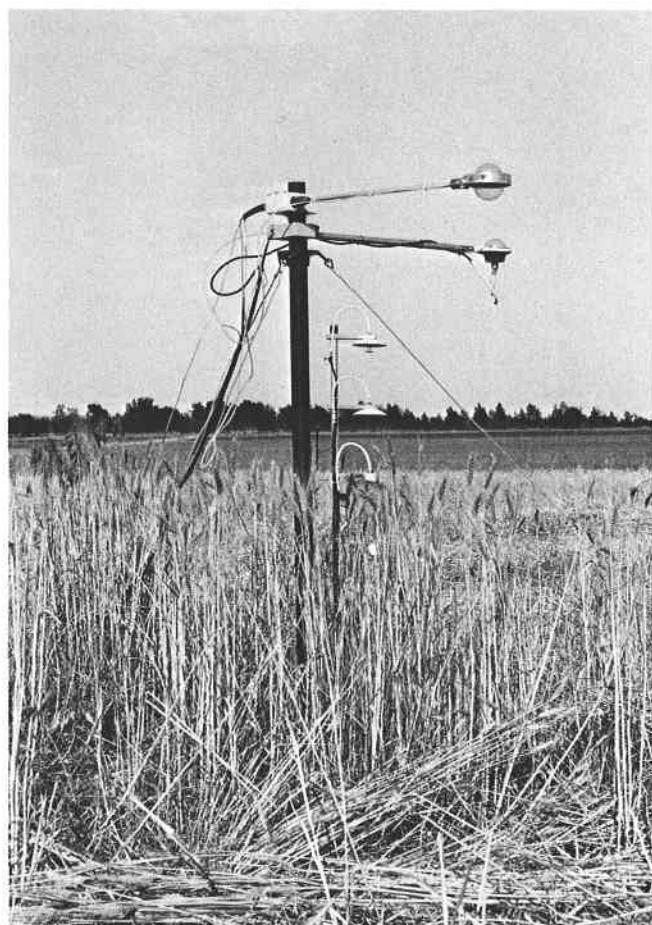
Ultimately, maps will be produced which indicate various statistics such as the date of the last occurrence of a particular temperature, the average length of the frost-risk period, and the average number and intensity of late-spring frosts. The Wheat Research Council is partially funding this work which is a collaborative venture with the Victorian Crops Research Institute, the Mallee Research Station, the South Australian Department of Agriculture and Waite Agricultural Institute in Adelaide.

Apart from frost risk, validation of satellite-measured land surface temperatures is important in its own right, and problems in interpretation are currently being investigated. The frost risk project has benefited this investigation.

Satellite instrumentation

Atmospheric pressure scanner

As Australia's weather is influenced so much by the Southern, Indian and Pacific Oceans, accurate meteorological information from these regions is crucial for accurate forecasting. Until now there has



R. Mleczko

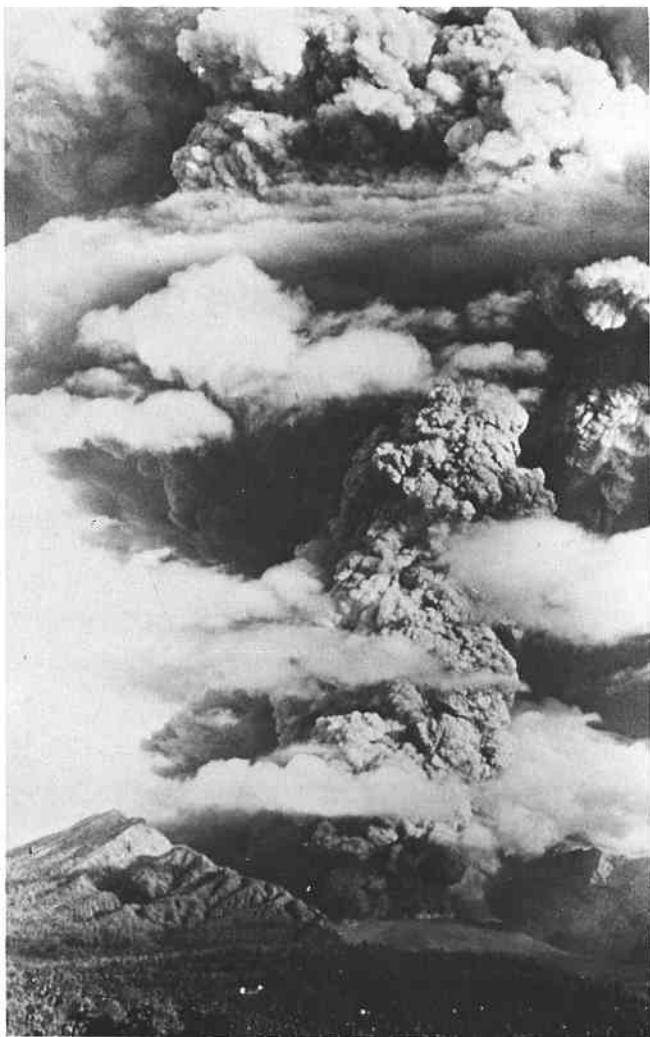
A range of sensors allows accurate measurement of the temperatures experienced at crop height during the growing period

been no way of measuring atmospheric surface pressure in areas where there are no monitoring stations. The development of a satellite-borne instrument to measure pressure will be of significant benefit to weather forecasting.

The Division is investigating a passive instrument in which a high-resolution spectrograph analyses reflected sunlight. The mass of oxygen in a column is determined from the amount of light absorbed by oxygen. As this gas is well mixed in the atmosphere, the mass of oxygen is directly related to atmospheric pressure.

An airborne prototype has been designed and manufactured by the Division in collaboration with the Division of Materials Science and Technology and AUSPACE. The prototype was mounted in the CSIRO F27 research aircraft and flown over both sea and land from Townsville in 1989. Results from this flight were encouraging. The technical simplicity of the instrument is a major advantage over complex microwave and lidar systems which have also been investigated.

The ability to resolve reflected and scattered radiation is crucial to the project. The next stage of testing will



Volcanic eruptions can present a hazard to aviation. The CSIRO volcanic ash detector is designed to distinguish volcanic ash clouds from normal rain clouds.

involve a site with a high tower or mountain. Sunlight reflected from the sea through a haze of aerosols will allow the spectrograph to receive both components of radiation in order to test pressure-retrieval procedures.

Measurement of surface temperature from space

Developmental work on the along track scanning radiometer (ATSR) continues. This instrument, which is designed to provide accurate satellite measurements of sea-surface temperature, is to be carried on the

European Remote-sensing Satellite (ERS-1). Launch is scheduled for early 1991.

ATSR data will be used for deriving global sea-surface temperature maps for climate models as well as for a variety of land and atmospheric applications. The instrument's dual view will be invaluable for measurements of land-surface temperature, snow and ice monitoring, and large-scale flood assessment. More detailed descriptions of the ATSR will be found in the Division's previous Research Reports.

Volcanic ash detection

In 1982, a British Airways B-747 aircraft, en route from Kuala Lumpur to Perth, plunged 7000 m after all four of its engines stopped. The engine failure was caused by the intake of particles from an ash cloud produced by the eruption of an Indonesian volcano earlier in the day. Eventually an engine was restarted and a successful emergency landing was made in Jakarta.

This is just one of many cases in which damage has occurred to a plane as a result of it inadvertently flying through volcanic debris. As a result, scientists and the aviation industry have been seriously considering practical means of detecting ash clouds and alerting commercial airlines of any danger.

The Division, in conjunction with the CSIRO Office of Space Science and Applications (COSSA), has proposed the development of an improved warning system using satellite instruments. The Japanese geostationary meteorological satellite provides high-resolution imagery for the Australian region every 30 minutes. The ash cloud detection method employs both visible and infrared wavelengths.

In addition, a sophisticated infrared sensor for use on board aircraft has been patented. Differential emission techniques are used to distinguish ash clouds from normal water and ice clouds. A two-dimensional image of cloud formations is produced and displayed on the pilot's instrument panel. Testing of such an airborne instrument will take place shortly.

WATER RESOURCES



Program Leader
Mr Barrie Hunt

Evaporation, condensation and precipitation constantly cycle water between the oceans, the atmosphere and the land. The Water Resources Program is improving our understanding of these processes, with particular emphasis on the way in which they influence Australia's climate. Numerical modelling at a range of different scales, and observations from field studies are being used to advance our knowledge.

Drought has brought great devastation to this country. Understanding the causes of drought and being able to predict its occurrence would clearly be extremely valuable. Current activity is focussing on the influence of El Niño sea-surface temperature anomalies in the Pacific Ocean. A coupled oceanic-atmospheric model is being developed and refined.

A number of field experiments have been undertaken to investigate regional cloud and rain systems. Model development is aimed at improved prediction of precipitation. Related to this work is a major consultancy study investigating the viability of cloud seeding over a large catchment area. The focus has been on the precipitation potential of winter storms.

The way in which land is used can have an impact on regional climate. The role of evaporation from irrigated areas is being examined. This work is leading to the development of detailed soil/vegetation/atmospheric dynamics models which will improve the representation of evaporation in climate models.

Drought studies

In order to provide a major focus for numerical modelling of drought, the Centre for Drought Research has been set up within the Division. The main objective of work carried out in the Centre will be to identify and model the way in which droughts form, develop and terminate.

Projects

- Drought studies
- Cloud processes and quantitative precipitation forecasting
- Surface moisture impact on climate
- Winter storms and cloud seeding

A testable drought prediction scheme has now been successfully developed. This relies on the inclusion of sea-surface temperature anomalies into the Division's four-level general circulation model.

El Niño sea-surface temperature anomalies have a major impact on the world's climate. Australian rainfall is very much influenced by such anomalies. Therefore, initial simulations have been restricted to El Niño events. The role of other sea-surface temperature anomalies will be assessed in future experiments.

The first simulations involved superimposing El Niño sea-surface temperature anomalies on the January temperature distribution used in the model. The model successfully reproduced the major observed rainfall changes associated with El Niño events, including droughts over eastern Australia and Venezuela, and increased rainfall in the central Pacific and Peru.

More realistic simulations, starting from different initial conditions, have also been conducted. Results confirm that the model accurately simulates the seasonal variability of rainfall for most of the regions influenced by El Niño. It is evident that multiple simulations are necessary because of the variations generated by slight changes to initial conditions.

As a specific test, a simulation of the 1988 United States drought was performed using the cold temperatures observed in the Pacific. The decreased rainfall over North America, as well as the corresponding enhanced rainfall experienced in Australia, was successfully modelled. The drought was associated with La Niña, the opposite phase of El Niño. This adds to confidence in the model as it has successfully simulated both types of events.

A simple model of the Pacific Ocean, 30°N to 30°S, has been developed. It is driven by wind distributions obtained by coupling the model to a Bureau of Meteorology atmospheric model. To date, experiments have concentrated on the El Niño of 1982. Predicted temperature anomalies at monthly intervals were inserted into the Division's four-layer model, resulting in simulations for the period from January 1982 to May 1983. Rainfall patterns over Australia were reproduced well for some months and



Dew — an important factor controlling local climate

poorly for others. Although the drought was predicted to break somewhat earlier than it actually did, overall the results were encouraging. If better simulations of sea-surface temperature anomalies can be made, useful information about rainfall variations over Australia, perhaps a year in advance, should be possible. There is still the need for a great deal of further research.

Surface moisture and climate

Evaporation of water is an important factor controlling the world's climate. Several studies by Divisional scientists have helped to clarify the impact of surface water on local atmospheric circulations and the depth of the boundary layer.

The influence of temperature on evaporation from wet surfaces has been investigated numerically. As temperature increases, more evaporation occurs, leaving less energy available to heat and expand the boundary layer. Aircraft observations from an irrigated region in north-east Colorado were analysed as part of a study aiming to identify inland breezes produced by the temperature contrasts between this region and its dry surroundings. This is one example of the way in which land-use can have an impact on local climate. The work was performed jointly with Colorado State University.

Local climate is also influenced by dew-fall. Dew forms at cold temperatures when water vapour close to the ground cools and condenses. Surface dew not only acts as a source of water to plants and soil in semi-arid regions, it affects boundary-layer growth during the morning. The amount of dew depends on numerous factors, including wind speed, absolute temperature, relative humidity, soil-canopy characteristics and cloudiness. Observations indicate that the horizontal movement of moisture in the nocturnal boundary layer can be responsible for

producing large amounts of dew. In areas where small-scale advection of atmospheric moisture is significant, dew-fall can be responsible for the accumulation on the surface of up to a millimetre of water by sunrise. One-dimensional models of the atmosphere cannot simulate such high dew events.

Precipitation forecasting

Modelling of clouds and rainfall

Clouds and precipitation are a central component of the earth's hydrological cycle. Latent heat released by clouds in the tropics drives global circulation, while the clouds themselves regulate incoming and outgoing radiation. The processes generating clouds and rain vary from large scale — of the order of thousands of kilometres — to just a few kilometres. As this range of resolution is beyond general circulation models, mesoscale or intermediate scale models have been devised to properly describe the detailed structure of cloud systems. The Regional Atmospheric Modeling System (RAMS), from Colorado State University, is being used at the Division for this purpose.

During the Australian Winter Storms Experiment, extensive observations of precipitation and cloud structure were made over the Thomson River catchment area in Victoria. Data obtained during periods of high rainfall will be used to test RAMS, which should be able to provide cloud information which will be helpful in evaluating the Experiment. Thus far, model simulations of rainfall rate and cloud properties compare well with aircraft, radiometer and surface observations. The Australian Water Resources Advisory Council (AWRAC) is supporting this work.

Structure of cold fronts

The summer-time cool change in south-eastern Australia is often difficult to forecast. The Cold Fronts Research Program in the early 1980s improved the understanding of such cool changes and resulted in development of a conceptual model of the process. Details of the Program can be found in the Division's 1983–1985 Research Report. More recently, Adelaide airport has been used as the site for further analysis of the structure of cold fronts. Information from the University of Adelaide VHF radar, and radiosonde ascents has extended the original model. The radar observations, in conjunction with routine Bureau of Meteorology observations, have been used to form a model of winter cold fronts. This model has been strengthened by studies associated with the Australian Winter Storms Experiment.

Tropical cyclone formation

It is likely that convective heating plays an important role in the development of tropical cyclones in northern Australia. Improved understanding of the formation of cyclones would be of great value to



The instrumented nose cone of the CSIRO F27 — used to obtain data about tropical cyclones. Turbulence vanes measure air motion.

forecasters. In 1987, the CSIRO F27 research aircraft and two US planes were used in an extensive investigation of tropical cyclone Irma while it was developing over the Gulf of Carpentaria. This study, with scientists from the National Center for Atmospheric Research (NCAR) and Texas A & M University, found that the cyclone developed a very broad rain-band with a relatively chaotic convective structure. At low and mid-levels in the atmosphere a strong wind maximum was observed. The importance of these features to the genesis of the tropical cyclone is being investigated using the Division's mesoscale model.

The Australian Winter Storms Experiment

The first Australian Winter Storms Experiment was conducted during July and August 1988. It supported a five-year Melbourne and Metropolitan Board of Works (MMBW) cloud seeding experiment designed to show whether, and to what extent, precipitation can be increased over the Thomson Dam. This is one of Melbourne's major water catchment areas, and is located near the Baw Baw Plateau, about 100 km east of the city.

The Experiment was specifically concerned with the interaction of winds with mountains and the associated development of clouds and precipitation. A range of sophisticated equipment was used. Omegasondes were launched from a nearby site to measure wind flow and thermodynamic variables. Rain and snowfall were measured using a series of digital bucket gauges. The CSIRO research aircraft sampled clouds at various



The radiometer, constructed at the Division for the Second Australian Winter Storms Experiment

heights in order to provide a thorough picture of cloud and precipitation development in the moist winds rising over the mountains.

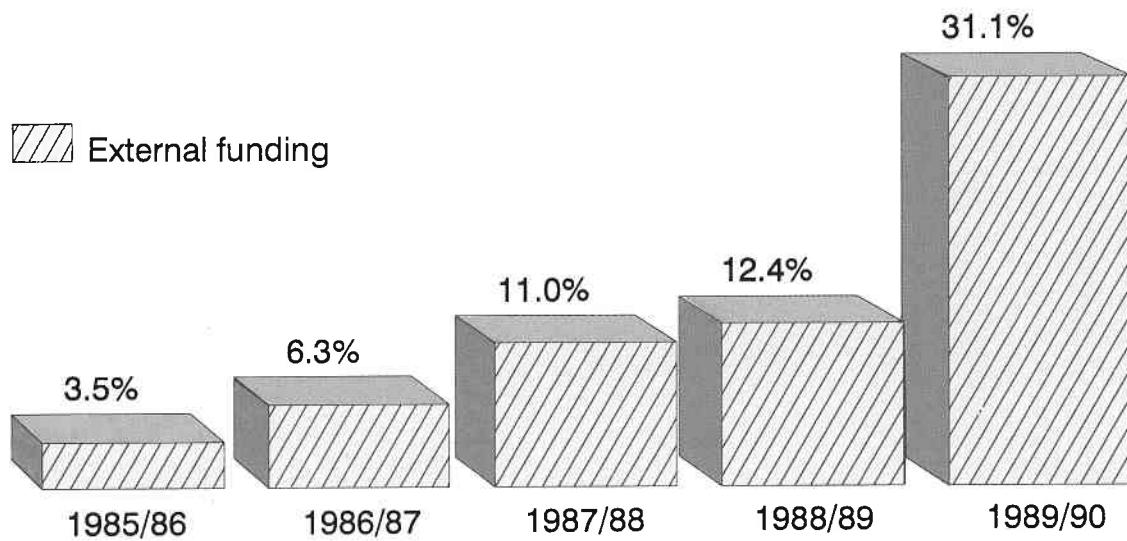
Remote sensing measurements of liquid water in the clouds were made using the Division's lidar as well as a microwave radiometer brought from the United States especially for this purpose. Such measurements are crucial for assessing whether seeding will be effective.

Preliminary results indicate that cloud seeding will be most effective when the wind is from the south-west. This usually occurs after the passage of a cold front and results in a significant amount of supercooled liquid water in air forced upwards by mountains in the area. The Division, acting as scientific consultant, has identified shallow orographic clouds upwind and over the mountains as a new class of clouds for seeding.

The Australian Winter Storms Experiment has been sponsored by the Division and also received support from the MMBW, the Australian Urban Water Research Association, the Bureau of Meteorology, Toyota Motor Company and QANTAS. Overseas support came from the United States National Science Foundation, the National Oceanic and Atmospheric Administration (NOAA) and the Desert Research Institute of Nevada.

The importance of the radiometer measurements indicated the need for a locally manufactured instrument. The Division has constructed a radiometer for use during the second Australian Winter Storms Experiment.

FINANCIAL SUMMARY



External funding 1985–1990. The Division's total expenditure for 1988/89 was \$6.71 million, 12.4% of which came from non-appropriation sources. The total expenditure for 1989/90 was \$8.77 million, with 31.1% of this coming from non-appropriation sources.

Research grants and external funding — 1988/89, 1989/90 combined

Subject	Contributor	Lead Scientist	Grant
Prediction of large-scale droughts in Australia	Australian Wool Corporation	B. Hunt	\$164 000
Frost risk	Department of Agriculture and Rural Affairs	M. Platt	\$54 000
Gaseous nitrogen emissions	Wheat Research Council	I. Galbally	\$10 000
Power station atmospheric dispersion	NERDDC	B. Sawford	\$70 000
Meridional carbon isotope variations	NERDDC	R. Francey	\$95 000
Quantitative precipitation modelling	AWRAC	B. Ryan	\$94 000
Drought prediction	AWRAC	B. Hunt	\$96 000
Development and testing of climate–biosphere relationship (Fellowship)	ARC	B. Pittock	\$30 000
ATSR development: sea surface temperature studies	ARC	I. Barton	\$17 000
Climate change co-ordination	DASETT	G. Pearman	\$129 500
Measurement program: upgrading greenhouse gas measurements	DASETT	R. Francey	\$239 000
Measurement program: historical records — Antarctic ice cores	DASETT	R. Francey	\$95 500
General circulation modelling of regional climate change	DASETT	J. McGregor	\$639 500
Detailed estimates of regional climate change	DASETT	B. Pittock	\$222 000
Modelling oceanic processes relevant to climate	DASETT	B. Hunt	\$210 000
Satellite monitoring of Australian regional climate conditions	DASETT	J. Garratt	\$265 000
Baseline air pollution program	Department of Science	G. Pearman	\$395 000
ATSR operational data processing package	DITAC	F. Prata	\$5 000
Atmospheric dispersion (Fellowship)	SEC (Vic)	B. Sawford	\$140 000
Greenhouse research — Victoria	EPA (Vic)	B. Pittock	\$150 000
Greenhouse research — NSW	SPCC (NSW)	B. Pittock	\$100 000
Greenhouse research — NT	CC (NT)	B. Pittock	\$80 000
Greenhouse research — WA	EPA (WA)	B. Pittock	\$60 000
Externally funded visits	Various		\$48 000
Intergovernmental Panel on Climate Change	DASETT	B. Hunt	\$20 000
Sub total			\$3 428 500
Research contracts and other revenue	Various		\$1 473 000
Total			\$4 901 500

SUPPORT SERVICES

Administration

The Administrative Group provides personnel and financial services to the Division including recruitment, budgeting, purchasing, word processing, reception, travel and transport facilities.

During the reporting period, the administration was involved in a major recruitment campaign due to the Division's success in obtaining external funds. Some 45 staff were recruited. The training program for administrative personnel continued with enhanced management information systems being introduced to cope with the changed administrative environment in the organisation.

A major building program was undertaken with the construction of the Climate Research Laboratory. The Administrative Group was required to transfer to this new building to enable its former area to be used for a major laboratory upgrade related to the new GASLAB.

Engineering Facilities Group

The engineering work of the Division is centrally controlled by the Divisional Engineer. It is divided into three areas: mechanical engineering, electronic instrument development, and site engineering.

The Site Engineering Group has been responsible for a number of major laboratory upgrades. A new CSIDA laboratory has been outfitted and the GASLAB has been created.

Significant mechanical and electronic projects are described below. In addition, numerous other projects have been undertaken, including construction of



Discussing job specifications in the Electronics Laboratory

sensors for the land-surface temperature study and work on the atmospheric pressure scanner and the convection tank.

Liquid water radiometer

The liquid water radiometer is a dual-channel microwave instrument. The higher frequency is sensitive to liquid water and the lower frequency to water vapour. The instrument was housed on a truck and will initially be located on Mt. Baw Baw as part of the Second Australian Winter Storms Experiment, described elsewhere in this report.

Automatic rain-water collectors

These collectors are now being successfully used in the Latrobe Valley. After rain is detected by a tipping-bucket gauge, a lid opens, exposing the collection bottle. There are eight such bottles and they advance once per day. The instrument is automatically controlled and logs rainfall data.

Sea-surface profiler

In order to verify data received from satellites, the sea-surface profiler has been designed to accurately monitor the temperature just above and below the sea. It will be towed behind the CSIRO research vessel, the *RV Franklin*, supplying accurate temperature data to an on-board logger.

Data acquisition and control system

The Electronics Group has designed data loggers for two different field experiments. One was required for the Melbourne Aerosol Study; the other for the Cape Grim Baseline Station. In both cases, flexible large-scale data storage was necessary. This has been achieved by producing an interface between the hardware to be controlled and a commercially-available data-acquisition card.

Consultation to industry

During the reporting period, a member of the Electronics Group was seconded to the BHP Central Research Laboratories. As Project Development Manager, the officer was responsible for the design, development and manufacture of three laser time-of-flight instruments for use in the iron-making industry.

Computer Services Group

This Division is one of the major users of computers in CSIRO. The increasing complexity of numerical models requires a powerful, sophisticated computing resource. The Computer Services Group provides a wide range of computer support services to all the

Division's computer users. A local area network provides rapid access from individual terminals, PCs, or workstations, to local and remote computer resources, including the CRAY Y-MP/2 supercomputer. The Group is responsible for the planning, installation and maintenance of the network and all centrally-operated computer facilities. In addition, support is provided to PCs, X-Terminals, workstations, printers and other hardware. The central facilities are available 24-hours-a-day.

A five-year plan, prepared in 1986, highlighted the need for significant development of the local facilities. This has now been largely implemented and the Division's Computing Committee is now preparing a new plan to guide the way into the mid 1990s.

Early in 1989, a site-wide Ethernet local-area network was installed, complimenting the existing data PBX serial network. Shortly after, a Silicon Graphics computer and three graphics workstations were purchased. The number of PCs in the Division has steadily increased; the majority are connected to the network. This provides access to a wide range of local facilities which are used extensively, particularly for analysis and presentation of large data sets.

In 1990, CSIRO's Cyber 205 supercomputer was replaced by the CRAY Y-MP/2 supercomputer, operated jointly by CSIRO, Leading Edge Technologies and Cray Research; collectively known as the Joint Supercomputer Facility. Many of the Division's research activities require access to the CRAY supercomputer. In order to facilitate this, a high speed link (2Mb/s) — the only such high-speed link to the supercomputer — has been installed between Aspendale and South Melbourne. This also connects the Divisional network to the newly formed AARNet, permitting remote access and electronic mail services to many thousands of computers world-wide.

Scientific Services Group

Scientific communication is becoming increasingly important. There is a need for the exchange of information within the Division, within CSIRO, with scientific colleagues in Australia and overseas, and with industry and the community. The Scientific Services Group aims to facilitate this exchange.

Newsletters are produced on a regular basis to inform the Division of activities and current research of fellow staff members. The DAR Bulletin reaches out to a wider audience, both within Australia and



The Division's centrally operated computer facility

overseas, providing descriptions of recent scientific work and listing publications. This exchange of information is just one of the ways in which the Division keeps scientific bodies around the world informed of its latest activities. A longer-term record of the Division's work is contained in the Research Report.

The graphics staff and the photographer offer a service which enables scientists to present their results in a polished, appealing manner.

An important task performed by the Group is scientific administration and scientific support for the Chief. The Organisation maintains a database of research projects, and Divisional entries are regularly up-dated.

The dissemination and sharing of information at conferences and workshops is actively encouraged. The organisation of such events forms part of the role of the Group.

Divisional Library

The Division maintains an extensive library which operates as part of the Australia-wide CSIRO Library Network. Implementation of CLINES, the Organisation's integrated on-line automated library system, is continuing. In addition, the library contributes to the Australian Bibliographic Network. This provides a range of reader services, including reference services, access to local and overseas databases, an in-house library newsletter, structured circulation of new material, and the provision of a local catalogue. Extensive use is made of new technologies including microcomputers and CD-ROM products.

VISITORS TO THE DIVISION

Dr C.M. Adam, Director, Institute of Industrial Technologies
Senator Brian Archer
Dr Jim Arnold, National Aeronautics and Space Administration, USA
Dr Claudio Battistoni, Director of CNR Project, Italy
Dr Steve Baughcum, The Boeing Company, USA
Mr John Bell, Department of Industry, Technology and Commerce
Dr Gary Betteridge, DSIR, New Zealand
Dr N.K. Boardman, Chief Executive of the CSIRO
Senator David Brownhill
Professor Bill Budd, University of Melbourne
Senator Bryant Burns
Dr John Bye, Flinders University, South Australia
Senator Bruce Childs
Mr Bob Chynoweth, Divisional Advisory Committee
Professor Adrienne Clarke, University of Melbourne
Senator John Coulter
Dr Andrew Crook, National Center for Atmospheric Research, USA
Senator John Devereux
Dr A.D. Donald, Director, Institute of Animal Production and Processing
Dr Richard Donnelly, National Oceanic and Atmospheric Administration, USA
Ms Robin Fleming, Department of Industry, Technology and Commerce
Dr R.H. Frater, Director, Institute of Information and Communications Technologies
Dr Leonardo Gastaldi, Director of CNR Project, Italy
Dr Roy Green, Director, CSIRO Institute of Natural Resources and Environment
Dr Angelo Guerrini, CNR Institute of Physics of the Atmosphere, Italy
Professor Cui Haiting, Department of Technical Training, China
Dr John Hallett, University of Nevada, USA
Mrs H. Hawke
The Hon. R.J.L. Hawke, Prime Minister of Australia
Dr Michael Healy, Bureau of Rural Research
Professor Ann Henderson-Sellers, Macquarie University
Dr Harry Hendon, University of Colorado, USA
Dr E.F. Henzell, Director, Institute of Plant Production and Processing
Dr T.E. Heyde, Principal Secretary, Office of the Chief Executive
Mr Les Hollings, former Editor-in-Chief of *The Australian*
Mr Hal Holmes, Divisional Advisory Committee
Professor Xu Jianmin, State Meteorological Administration, China
Mr Luo Jibin, State Meteorological Administration, China
Mr Zou Jingmeng, State Meteorological Administration of China
Dr E.R. Johnson, University College, United Kingdom
Dr Christer Johansson, University of Stockholm, Sweden
Hon. Barry Jones, Minister for Science
Dr Phil Jones, University of East Anglia, United Kingdom
Dr Ramesh Kakar, National Aeronautics and Space Administration, USA
Mr Doug Keeley, Department of Industry, Technology and Commerce
Dr Gerard Lambert, Centre Nationale Recherche Scientifique, France

Ms Judy Lawrence, Ministry for the Environment, New Zealand
Dr Mervyn Lynch, Curtin University of Technology, Western Australia
Dr Mike Manton, Bureau of Meteorology Research Centre
Dr George McDonough, National Aeronautics and Space Administration, USA
Dr Tateki Mizuno, National Research Institute for Pollution and Resources, Japan
Dr Mitchell Moncrieff, National Center for Atmospheric Research, USA
Mr Vin Morgan, Australian Antarctic Division
Dr R.E. Munn, University of Toronto, Canada
Professor He Yida, Department of Research and Development, China
Dr K. Okamoto, Communications Research Laboratory, Japan
Dr John Owen, British Meteorological Office
Dr Tim Palmer, ECMWF, United Kingdom
Mr Wu Peizhong, State Oceanic Administration, Department of Science and Technology, China
Dr Alan Plumb, Massachusetts Institute of Technology, USA
Professor Tong Qingxi, Department of Research and Development, China
Mr Stefan Rahmstorf, Victoria University, New Zealand
Mr Alan Rainbird, Divisional Advisory Committee
Dr A.F. Reid, Director, Institute of Minerals, Energy and Construction
Senator Graham Richardson, Minister for the Environment
Dr Lawrie Rikus, Bureau of Meteorology Research Centre
Professor T. Sakata, Tokai University Research and Information Centre, Japan
Dr Michael Schlesinger, University of Illinois, USA
Mr N. Shigeta, Space Communications Development Division, Japan
Mr Deng Shuchu, State Astronautical Office, China
Dr David Stock, Washington State University, USA
Dr John Stocker, Chief Executive, CSIRO
Dr Pieter Tans, University of Colorado, USA
Dr John Theon, National Aeronautics and Space Administration, USA
Mr Otto Thiele, National Aeronautics and Space Administration, USA
Mr Fan Tianxi, Satellite Meteorological Centre, China
Dr Harry van Loon, National Center for Atmospheric Research, USA
Dr Roxana Wajsowicz, Oxford University, United Kingdom
Dr Andrew Willmott, University of Exeter, United Kingdom
Dr Greg Wilson, National Aeronautics and Space Administration, USA
Mr Colin Wookey, Australian Antarctic Division
Dr David Wratt, New Zealand Meteorological Service
Mrs Wang Xiaomin, State Meteorological Administration of China
Mr Zhao Yunde, State Meteorological Administration of China
Mr Wei Zhongquan, Academy for Space Technology of China
Dr John Zillman, Bureau of Meteorology

AFFILIATIONS

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

Abbs, Debbie

Honorary Secretary, Australian Meteorological and Oceanographic Society (AMOS)

Ayers, Greg

Associate Editor, *Australian Meteorological Magazine and Clean Air*

Member, Cape Grim Baseline Air Pollution Station (CGBAPS) Working Group

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)
President of AMOS

Barton, Ian

Australian Representative, Committee of Earth Observation Satellites (CEOS) Working Group on Calibration and Validation

Member, Along Track Scanning Radiometer for ERS-1, ESA Science Team

Member, NASA MODIS Science Team

Beer, Tom

Convener, Awards Sub-Committee, AMOS

Member, Editorial Board, *Australian Maritime Atlas*
Member, Executive Committee of Simulation Society of Australia

Bouma, Willem

Member, CGBAPS Working Group

Member, Australia and New Zealand Environment Council (ANZEC) Greenhouse Task Force

Member, Judging Panel for 1989 BHP Prize

Secretary, Divisional Advisory Committee

Davy, Liz

Victorian Divisional Representative, CLINES User Group

Francey, Roger

Editor, *Journal of Atmospheric Chemistry*, SABOAC II issues

Member, CGBAPS Working Group

Fraser, Paul

Co-Chairman, Trace Gas Trends Group, Montreal Protocol Review of Stratospheric Ozone

Co-Chairman, Trace Gas Trends Group, NASA Ozone Trends Panel

Co-Editor, *Baseline 1987*

CSIRO Representative, Global Atmospheric Gases Experiment (GAGE)

Member, ANZEC Ozone Protection Consultative Committee

Member, CGBAPS Working Group

Member, International Ozone Commission

Member, National Health and Medical Research

Council (NHMRC) Expert Panel on Climate Change and Health Effects

Member, NHMRC Working Party on Chlorofluorocarbons and Alternative Aerosol Propellants

Member, NHMRC Working Party on Health Effects of Ozone Layer Depletion

Member, Royal Society of Victoria Working Party reviewing the Victorian Government's Ozone Layer Act

Member, United Nations Environment Program's Co-ordinating Committee on the Ozone Layer

Member, Working Group 1, Intergovernmental Panel on Climate Change, sub-panel on methane, non-methane hydrocarbons and carbon monoxide

Scientific Adviser, Aerosol Association of Australia

Scientific Adviser, Association of Fluorocarbon Consumers and Manufacturers (AFCAM)

Frederiksen, Jorgen

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

Galbally, Ian

Associate Editor, *Journal of Atmospheric Chemistry*
Convener and Report Editor, International Global Atmospheric Chemistry Programme

Member, Air Environment Research Committee, Victoria

Member, CGBAPS Working Group

Member, Commission on Atmospheric Chemistry and Global Pollution of International Association for Meteorology and Atmospheric Physics (IAMAP)

Member, Editorial Board, *Tellus*

Member, Executive Committee, NASA Global Tropospheric Experiment/Pacific Exploratory Mission

Member, Expert Group on Greenhouse Gases of the Joint Scientific Committee of the World Climate Research Programme

Member, Ministerial Consultation Group on Acid Rain, Victoria

Member, Scientific Advisory Committee of SCOPE Biospheric Trace Gas Emissions Project

Garratt, John

Member, Editorial Board, *Boundary-Layer Meteorology*
Member, Editorial Committee, *Quarterly Journal of the Royal Meteorological Society*

Member, WMO/CAS Working Group on Boundary-Layer Problems

Gras, John

Member, CGBAPS Working Group

Hughes, Roger

Editor, *Pure and Applied Geophysics*

Hunt, Barrie

Associate Editor, *Climate Dynamics*

Member, National Committee of Atmospheric Sciences

Member, Scientific Committee for Solar Terrestrial Physics

Long, Alex

Associate Editor, *Journal of Climate and Applied Meteorology*

Manins, Peter

Associate Editor, *Australian Meteorological Magazine*

and *Clean Air*
Member, Air Environment Research Committee

Paltridge, Garth
Chairman, National Committee for Atmospheric Science
Member, International Radiation Commission

Pearman, Graeme
Co-Investigator, NASA/EOS Interdisciplinary Investigation titled: Interdisciplinary studies of the relationship between climate, ocean circulation, biological processes and renewable marine resources in the Australasian region
Guest Editor, *Journal of Atmospheric Chemistry*
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, CGBAPS Working Group
Member, IGBP working group on Regional Research Centres
Member, International Editorial Advisory Boards, *The Encyclopedia of Climate and Weather* and *Journal of Climate Dynamics*
Member, International Panel 6 on Global Analysis, Interpretation and Modelling of the IGBP
Member, Society of Automotive Engineers, Australia, Environmental Pollution Advisory Committee
Member, South Australian Sea-Level Advisory Committee

Pittock, Barrie
Member, Australian National Committee for the Environment
Member, Editorial Boards of *Climate Change*, *International Journal of Climatology* and *Journal of Natural Hazards*
Member, IAMAP/IUGG International Commission on Climate
Member, SCOPE Standing Committee on Publications

Platt, Martin
Chairman, Australian Institute of Physics, Remote Sensing Group
Member, CGBAPS Working Group
Leader, Science Team for ECLIPS and Joint Organizer

of the Program
Member, International Committee for Laser Atmospheric Studies
Member, Science Team for Lidar In-Space Technology Experiment (LITE)
Rapporteur on Clouds, International Radiation Commission, IAMAP

Prata, Fred
Co-Chairman, Volcanic Ash Detection and Air Safety Working Group, COSSA
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*

Smith, Ian
Convener, Education Sub-committee, AMOS

Tucker, Brian
Chairman, Latrobe Valley Airshed Study Steering Committee
Member, Australian Environment Council Standing Committee
Member, Australian Ionizing Radiation Advisory Committee
Member, Cape Grim Management Committee
Member, Drought Policy Review Task Force
Member, Executive Committee of Scientific Committee on Oceanic Research
Member, National Bushfire Research Unit Steering Committee
President, IAMAP

Turner, Peter
Member, Chisholm Institute of Technology Course Committee for the Graduate Diploma in Computer Graphics
Member, Victorian Remote Sensing Committee

Lecture courses presented at Australian tertiary institutions

The Division recognizes the importance of maintaining strong links with universities and other tertiary institutions. A number of staff have presented graduate and undergraduate courses:

Beer, Tom

University of Melbourne, 1988

Introductory Physical Oceanography to Second Year Meteorology students

Bouma, Willem

Footscray Institute of Technology, 1989

Atmospheric Physics, Ozone Depletion and the Greenhouse Effect to Applied Physics students

Etheridge, David

University of Melbourne, 1988, 1989

General Climatology to Third Year Science students

Fraser, Paul

Wollongong University, 1988, 89

Atmospheric Chemistry to Third Year Chemistry students

Garratt, John

Monash University, 1988, 1989, 1990

The Atmospheric Boundary Layer to Honours and Masters students

Hughes, Roger

University of Melbourne, 1988

Variational Methods to Fourth Year Electrical Engineering students

McGregor, John

Monash University, 1989, 1990

Atmospheric Environment to Third Year Mathematics students

Manins, Peter

Royal Melbourne Institute of Technology, 1988, 1990

Air Pollution and Power Engineering to Engineering students

Pittock, Barrie

Monash University, 1988, 1989

Environmental Impacts of Nuclear War to First Year Geography students

Melbourne University, 1990

Greenhouse Effect and Agriculture to Fourth Year Agriculture students

Ryan, Brian

University of Melbourne, 1990

Tropical Clouds and Cloud Systems to Honours and Graduate Meteorology students

Smith, Ian

University of Melbourne, 1990

Solar and Terrestrial Radiation to Third Year Meteorology students



Regular seminars ensure that staff and visitors are informed of scientific activities both within and outside the Division

PUBLICATIONS

Abbs, D.J. and W.L. Physick (1988) The summertime wind regime of the Latrobe Valley. *Clean Air*, **22**(4), 146–147.

Allan, R.J. (1989) ENSO and climatic fluctuations in Australia. In: *CLIMANZ 3: Proceedings of the Third Symposium on the Late Quaternary Climatic History of Australasia*. Melbourne, edited by T.H. Donnelly and R.J. Wasson, Canberra, CSIRO Division of Water Resources, p. 49–61.

Allan, R.J. and J.I. Pariwono (1990) Ocean–atmosphere interactions in low-latitude Australasia. *International Journal of Climatology*, **10**(2), 145–178.

Ingemann S., S. Hammerum, P.J. Derrick, C.E. Allison, R.H. Fokkens, E. Kluft and N.M.M. Nibbering (1989) Secondary isotope effects: Zero-point energies, critical energies and statistical weight effects. *Advances in Mass Spectrometry*, **11**, 772.

Allison, C.E. and T.B. McMahon (1990) How strong is the SiC bond in fluoro- and methyl-substituted silaethylenes? An experimental determination of bond energies. *Journal of the American Chemical Society*, **112**, 1672.

Ayers, G.P., J.L. Gras, R.W. Gillett and S.T. Bentley (1988) The Latrobe Valley aerosol/visibility study. *Clean Air*, **22**(4), 225–226.

Ayers, G.P. and J.P. Ivey (1989) Rainwater methanesulfonate. In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.31–33.

Ayers, G.P., H. Berresheim, M.O. Andreae and R.W. Gillett (1989) Distribution of biogenic sulfur compounds in the remote southern hemisphere. In: *Biogenic Sulfur in the Environment*, edited by E. Saltzman and W.J. Cooper, Washington, DC. American Chemical Society, p.352–366.

Ayers, G.P. (1990) The Latrobe Valley aerosol/visibility study: a summary of results. *Clean Air*, **24**(1), 18–26.

Ayers, G.P., J.L. Gras, R.W. Gillett and S.T. Bentley (1990) Methanesulfonate in rainwater at Cape Grim, Tasmania. *Tellus*, **42B**(2), 217–222.

Berresheim, H., Ayers G.P., R.W. Gillett *et al.* (1990) Airborne measurements of dimethylsulfide, sulfur dioxide, and aerosol ions over the Southern Ocean south of Australia. *Journal of Atmospheric Chemistry*, **10**(3), 341–370.

Noller, B.N., N.A. Curry, G.P. Ayers and R.W. Gillett (1990) Chemical composition and acidity of rainfall in the Alligator Rivers region, Northern Territory, Australia. *Science of the Total Environment*, **91**, 23–48.

Baines, P.G. (1988) Rossby wave hydraulics. *Ocean Modelling*, **79**, 1–6.

Baines, P.G. and F. Guest (1988) The nature of upstream blocking in uniformly stratified flow over long obstacles. *Journal of Fluid Mechanics*, **188**, 23–46.

Baines, P.G. (1989) Guest editor. Laboratory experiments in geophysical fluid dynamics: current progress and new horizons. *Dynamics of Atmospheres and Oceans*, **13**(1–2).

Baines, P.G. (1989) Laboratory simulation of topographic effects on atmospheric flows in stable conditions. *Clean Air*, **23**(2), 74–76.

Baines, P.G. (1989) The physical oceanography of Australian waters. *Australian Meteorological Magazine*, **37**(3), 155–165.

Baines, P.G. (1989) Topographic effects on the mean tropospheric flow pattern around Antarctica. In: [Preprints] *Third International Conference on Southern Hemisphere Meteorology*, Boston, American Meteorological Society, p. 249–250.

Baines, P.G. and K. Fraedrich (1989) Topographic effects on the mean tropospheric flow patterns around Australia. *Journal of the Atmospheric Sciences*, **46**(22), 3401–3415.

Baines, P.G. and H.P. Leonard (1989) The effect of rotation on flow of a single layer over a ridge. *Quarterly Journal of the Royal Meteorological Society*, **115**(486), 293–308.

Baines, P.G. and P.C. Manins (1989) The principles of laboratory modelling of stratified atmospheric flows over complex terrain. *Journal of Applied Meteorology*, **28**(11), 1213–1225.

Baines, P.G. (1990) What's interesting and different about Australian Meteorology? *Australian Meteorological Magazine*, **38**, 123–141.

Castro, I.P., W.H. Snyder and P.G. Baines (1990) Obstacle drag in stratified flow. In: *Proceedings of the Royal Society of London, Series A*, **429**, 119–140.

Barton, I.J. (1988) Atmospheric absorption in the VAS split-window channels. *Journal of Applied Meteorology*, **27**(8), 965–969.

Barton, I.J. (1988) ERS-1 calibration and validation in Australasia. *COSSA Publication No.020A*, ISBN: 0 643 04756 5, 27pp.

Barton, I.J. (1989) Digitization effects in AVHRR and MCSST data. *Remote Sensing of Environment*, **29**(1), 87–89.

Barton, I.J. and R.P. Cechet (1989) Comparison and optimization of AVHRR sea surface temperature algorithms. *Journal of Atmospheric and Oceanic Technology*, **6**(6), 1083–1089.

Barton, I.J. and R.P. Cechet (1989) High level cloud near alpine region of south-eastern Australia. *Weather*, **44**(11), 446–447.

Barton, I.J., A.M. Zavody, D.M. O'Brien, D.R. Cutten, R.W. Saunders and D.T. Llewellyn-Jones (1989) Theoretical algorithms for satellite-derived sea surface temperatures. *Journal of Geophysical Research*, **94**(D3), 3365–3375.

Barton, I.J. (1990) The Along Track Scanning Radiometer. In: *Proceedings of the Fifth National Space Engineering Symposium 1989*. Institution of Engineers, Australia, ISBN 85825 490 5, p. 61–65.

Barton, I.J. and J.M. Bathols (1990) Monitoring floods with AVHRR. *Remote Sensing of Environment*, **30**(1), 89–94.

Coppin, P.A., E.F. Bradley, I.J. Barton and J.S. Godfrey (1990) Simultaneous observations of bulk sea temperature, radiative SST and satellite SST in the equatorial Pacific. *BMRC Research Report*, **21**, 50–53.

Beardsmore, D.J. and G.I. Pearman (1988) Baseline carbon dioxide concentrations. In: *Baseline Atmospheric Program (Australia) 1986*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.53–58.

Beardsmore, D.J. and G.I. Pearman (1989) Baseline carbon dioxide concentrations. In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.29–31.

Beer, T., A.M. Gill and P.H.R. Moore (1988) Australian bushfire danger under changing climatic regimes. In: *Greenhouse: Planning For Climate Change*, edited by G.I. Pearman. CSIRO, Melbourne, p.421–427.

Beer, T. (1989) *The Applied Environmetrics Oceanographic Tables*. Applied Environmetrics, Melbourne, 38pp & disk.

Beer, T. (1989) A simple model for predicting dust deposition in the vicinity of open-cut coal mines. *Clean Air*, **23**, 21–23.

Beer, T. (1989) [Book Review] *Numerical Modelling Application to Marine Systems*, edited by J. Noye. *AMSA Bulletin*, **108**, 17–18.

Hart B.T., G. Day, A. Sharp-Paul and T. Beer (1989) Water quality variations during a flood event in the Annan River, north Queensland. *Australian Journal of Marine and Freshwater Research*, **39**(2), 225–243.

Beer, T. (1990) *The Applied Environmetrics Meteorological Tables*. Applied Environmetrics, Melbourne, 58pp and disk.

Beer, T. (1990) Modelling rainfall as a fractal process. In: *Mathematics and Computers In Simulation*, **32**, 119–124.

Beer, T. (1990) Optimizing performance of finite-difference schemes. *Mathematical and Computer Modelling*, **13**(4), 73–86.

Bell, R.C. (1989) [Book Review] *Complexity of Parallel Implementation of Domain Decomposition Techniques for*

Elliptic Partial Differential Equations, by W.D. Gropp and D.E. Keyes. *Computing Reviews*, **30**(8), 422.

Bennett, J.W., R.J. Turner and A.S. Woodyatt (1989) Mode activated remote switch (MARS). *Technical Note, BHP Research and New Technology, Central Research Laboratories*, CRL/TN/34/89. 7pp.

Bennett, J.W., A.B. Duval, J.C. Scott and P.C. Mall (1989) Optical raceway sensing. *Technical Note, BHP Research and New Technology*, Central Research Laboratories.

Bennett, J.W. (1990) BHP develops laser instrumentation. *Process and Control Engineering*, **43**(3), 43–46.

Borgas, M.S. and J.B. Grotberg (1988) Monolayer flow on a thin film. *Journal of Fluid Mechanics*, **193**, 151–170.

Borgas, M.S. (1989) Recent modelling developments for turbulent-dispersion models. *Clean Air*, **23**(3), 124–126.

Borgas, M.S. and T.J. Pedley (1990) Non-uniqueness and bifurcation in annular planar channel flows. *Journal of Fluid Mechanics*, **214**, 229–250.

Bouma, W.J. (1989) [Book Review] *Planet Under Scrutiny: An Australian Remote Sensing Glossary*, by D.C. Griersmith and J. Kingwell. Canberra, AGPS, 1988. *Search*, **20**(2), 67.

Bouma, W.J. and G.I. Pearman (1989) The greenhouse effect: facts, predictions and uncertainties. In: *Proceedings of the Fifth Australian Agronomy Conference*, Australian Society of Agronomy, p. 279–288.

Bouma, W.J. and G.I. Pearman (1989) Greenhouse gases and the greenhouse effect. *Chemistry in Australia*, **56**(8), 268–271.

Wong, M.W., R.H. Nobes, W.J. Bouma and L. Radom (1989) Isoelectronic analogues of molecular nitrogen: Tightly-bound multiply-charged species. *Journal of Chemical Physics*, **91**, 2971–2979.

Bouma, W.J., P.N. Holper, R.J. Francey (1990) The global atmosphere — current status. In: *Proceedings of Environment '90: International Environmental Solutions Conference*. Carlingford, N.S.W.

Morris, B., T. Sadler and W.J. Bouma (1990) *The greenhouse effect: exploring the theory*, CSIRO Melbourne, 50pp.

Cai, W. and G.W. Lennon (1988) Upwelling in the Taiwan Strait in response to wind stress, ocean circulation and topography. *Estuarine, Coastal and Shelf Science*, **26**, 15–31.

Cai, W., R.B. Schahinger and G.W. Lennon (1989) Layered models of coastal upwelling: a case study of the South Australian region. *Modeling Marine System*, **1**, 73–91.

Cechet, R.P. and I. Allison (1988) Identification and discrimination of Antarctic (sea) ice types from NOAA AVHRR imagery. In: *Proceedings of the Symposium on Space and Airborne Technology Applications*, Hobart, Tasmania.

Derek, N. and S. Whittlestone (1989) Concentrations of ^{222}Rn . In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.44.

Dilley, A.C. (1989) The CSIRO System for Interactive Data Analysis (CSIDA): a system for acquiring, processing and displaying meteorological satellite data. In: *Report of the Workshop on Remote Sensing for Land and Sea Resource Surveys and Evaluation in the Pacific: Applications, Co-ordination and Training*, Port Vila, Vanuatu. ESCAP/UNDP Regional Remote Sensing Programme. pp 65–72.

Dix, M. and I. Simmonds (1989) The use of mean atmospheric parameters in the calculation of modelled mean surface heat fluxes over the world's oceans. *Journal of Physical Oceanography*, **19**(2), 205–215.

Dix, M., I. Simmonds, P. Rayner and G. Trigg (1989) Local and remote response to zonally uniform sea-surface temperature in July general circulation model. *International Journal of Climatology*, **9**(2), 111–131.

Durre, A.M. and T. Beer (1989) Wind information prediction study: Annaburroo meteorological data analysis, *CSIRO Division of Atmospheric Research Technical paper 17*.

Guttmann, A.J. and I.G. Enting (1988) The number of convex polygons on the square and honeycomb lattice. *Journal of Physics A: Mathematics and General*, **21**, L467–L474.

Newsam, G.N. and I.G. Enting (1988) Inverse problems in atmospheric constituent studies: I. Determination of surface sources under a diffusive transport approximation. *Inverse Problems*, **4**(4), 1037–1054.

Enting, I.G. and F.J. Robbins (1988) Trajectory analysis of selected baseline CO₂ data. In: *Baseline Atmospheric Program (Australia) 1986*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p35–39.

Enting, I.G. (1989) CO₂ measurements by CSIRO (Australia). In: *The Statistical Treatment of CO₂ Data Records*, edited by W.P. Elliott. NOAA Technical Memorandum ERL ARL-173, p43–50.

Enting, I.G. (1989) Some comments on Kalman filtering of CO₂ data. In: *The Statistical Treatment of CO₂ Data Records*, edited by W.P. Elliott. NOAA Technical Memorandum ERL ARL-173, p101–111.

Enting, I.G. (1989) Studies of baseline selection criteria for Cape Grim, Tasmania. In: *The Statistical Treatment of CO₂ Data Records*, edited by W.P. Elliott. NOAA Technical Memorandum ERL ARL-173, p51–60.

Enting, I.G. (1989) Time series studies of CO₂ data in the Division of Atmospheric Research, CSIRO, Australia. In: *The Statistical Treatment of CO₂ Data Records*, edited by W.P. Elliott. NOAA Technical Memorandum ERL ARL-173, p91–100.

Enting, I.G. and A.J. Guttmann (1989) Area-weighted moments of convex polygons on the square lattice. *Journal of Physics A: Mathematics and General*, **22**, 2639–2642.

Enting, I.G. and A.J. Guttmann (1989) Polygons on the honeycomb lattice. *Journal of Physics A: Mathematics and General*, **22**(9), 1371–1384.

Enting, I.G. and M.R. Manning (1989) The seasonal cycle of CO₂ at Mauna Loa. A re-analysis of a digital filtering study. In: *The Statistical Treatment of CO₂ Data Records*, edited by W.P. Elliott. NOAA Technical Memorandum ERL ARL-173, p124–131.

Enting, I.G. and J.V. Mansbridge (1989) Seasonal sources and sinks of atmospheric CO₂: direct inversion of filtered data. *Tellus* **41B**(2), 111–126.

Enting, I.G. and F.J. Robbins (1989) Asymmetric filters for analyzing time series of atmospheric constituent data. *Tellus* **41A**(2), 109–114.

Enting, I.G. and A.J. Guttmann (1990) On the area of square lattice polygons. *Journal of Statistical Physics*, **58**(3/4), 475–484.

Enting, I.G. and G.N. Newsam (1990) Inverse problems in atmospheric constituent studies: II. Sources in the free atmosphere. *Inverse Problems*, **6**(3), 349–362.

Etheridge, D.M., G.I. Pearman and F. de Silva (1988) Atmospheric trace-gas variations as revealed by air in an ice core from Law Dome, Antarctica. *Annals of Glaciology*, **10**, 28–33.

Etheridge, D.M. (1989) Dynamics of the Law Dome ice cap, Antarctica, as found from bore hole measurements. *Annals of Glaciology*, **12**, 46–50.

Etheridge, D.M. and V.I. Morgan (1989) The records of air temperature, ice sheet extent and atmospheric trace gas concentrations in ice cores. In: *CLIMANZ 3: Proceedings of the Third Symposium on the Late Quaternary Climatic History of Australasia*. Melbourne, edited by T.H. Donnelly and R.J. Wasson. Canberra, Division of Water Resources, p. 107–113.

Etheridge, D.M. and Wookey, C.W. (1989) Ice core drilling at a high accumulation area of Law Dome, Antarctica, 1987. In: *Proceedings of the Third International Workshop on Ice Core Drilling Technology*. Grenoble, France.

Etheridge, D.M. (1990) Scientific plan for deep drilling on Law Dome. *ANARE Research Notes* 76.

Francey, R.J. and H.S. Goodman (1988) The DAR stable isotope reference scale for CO₂. In: *Baseline Atmospheric Program*

(Australia) 1986. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p40-46.

Francey, R.J., G.I. Pearman and P.J. Fraser (1988) Meridional carbon isotope variations. *NERDDP Report*. Australian Department of Primary Industries and Energy, 32 pp.

Polach, H., M.J. Head and R.J. Francey (1988) Atmospheric $^{14}\text{C}/^{12}\text{C}$ at Cape Grim, 1986. In: *Baseline Atmospheric Program (Australia) 1986*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p 59.

Francey, R.J. (1989) [Letter to the Editor] Comment on "Rapid response of tree cellulose radiocarbon content to changes in atmospheric $^{14}\text{CO}_2$ concentration", by P.M. Grootes *et al.* *Tellus*, **41B**, 484-485.

Francey, R.J. (1989) Report on SABOAC II (The Scientific Application of Baseline Observations of Atmospheric Composition) Aspendale, Australia. In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.68-69.

Francey, R.J. and K.T. Hubick (1989) The latitudinal dependence of tree ring $^{13}\text{C}/^{12}\text{C}$. *Nature*, **333**, 712.

Francey, R.J., P.J. Fraser and G.I. Pearman (1989) The CSIRO meridional gradient study of CO_2 isotopes. *Geophysical Monitoring for Climate Change (NOAA)*, 1988 Annual Report, No. 17, 91-93.

Francey, R.J., H. Polach and M.J. Head (1989) Atmospheric $^{14}\text{C}/^{12}\text{C}$ at Cape Grim 1986, 1987. In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, pp 30-31.

Fraser, P.J. (1988) Atmospheric ozone: observations and modelling. In: *Environmental, Health and Economic Implications of the Use of Chlorofluorocarbons as Aerosol Propellants and Possible Substitutes*, edited by P.J. Fraser. Australian Environment Council — National Health and Medical Research Council, Australian Government Publishing Service, Canberra, p.15-26.

Fraser, P.J. (1988) Changes in atmospheric ozone: observations and modelling. In: *Environmental, Health and Economic Implications of the Use of Chlorofluorocarbons as Aerosol Propellants and Possible Substitutes*, edited by P.J. Fraser. Australian Environment Council — National Health and Medical Research Council, Australian Government Publishing Service, Canberra, p.41-55.

Ehhalt, D., P.J. Fraser, D. Albritton, R. Cicerone, A. Khalil, M. Legrande, Y. Makide, F. Rowland, L. Steele and R. Zander (1988) Trends in source gases. In: *Present State of Knowledge of the Upper Atmosphere 1988: An assessment Report*, NASA Reference Publication 1208, p.78-80.

Fraser, P.J. (1989) The Antarctic ozone hole. In: *The Ozone Layer and Health, Transactions of the Menzies Foundation*, **15**, p.37-48.

Fraser, P.J. (1989) Chlorofluorocarbons and stratospheric ozone. *Chemistry in Australia*, **56**(8), 272-275.

Fraser, P.J. (1989) The effect of halons on the ozone layer. In: *Putting Out the Fire: Ozone Protection and the Future of Halons: Symposium Proceedings*, Environment Protection Authority, p.13-18.

Fraser, P.J. (1989) Stratospheric ozone. In: *Health Effects of Ozone Layer Depletion: A Report of the NHMRC Working Party*, National Health and Medical Research Council, Canberra. Australian Government Publishing Service. p.8-36.

Fraser, P.J. and S. Coram (1989) Atmospheric methane, carbon dioxide by gas chromatography. In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.39-40.

Fraser, P.J. and N. Derek (1989) Atmospheric halocarbons, nitrous oxide and methane — the GAGE program. In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.34-38.

Fraser, P.J., R.A. Rasmussen and M.A.K. Khalil (1989) Atmospheric observations of chlorocarbons, nitrous oxide, methane, carbon monoxide and hydrogen from Oregon Graduate Center flask sampling program. In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.40-44.

Fraser, P.J. (1990) Monitoring CFCs in the atmosphere. In: *CFCs and the Environment: Forum Proceedings*. Canberra, ACT., Australian Institute of Refrigeration, Air Conditioning and Heating, p. 1-8.

Chanin, M., D. Ehhalt, P.J. Fraser, J. Frederick, J. Gille, M. McCormick, G. Megie, and M. Schoeberl (1990) Global Trends, Chapter 2, In: *Scientific Assessment of Stratospheric Ozone: 1989*, Volume 1, World Meteorological Organization Global Ozone Research and Monitoring Project, Report Number 20, 163-281.

Frederiksen C.S. and J.S. Frederiksen (1988) Form drag instability on beta-planes. *South Australian Institute of Technology Report*, MACS 88/01, pp.1-41.

Kleeman R., J.S. Frederiksen and R.C. Bell (1988) Statistical dynamics of quasi-geostrophic flows. In: *Computational Techniques and Applications*: CTAC-87, Elsevier, 347-356.

Frederiksen, J.S. (1989) The role of instability during the onset of blocking and cyclogenesis in northern hemisphere synoptic flows. *Journal of the Atmospheric Sciences*, **46**(8), 1076-1092.

Frederiksen, J.S. and C.S. Frederiksen (1989) Flow over topography and instability on beta-planes: the effects of different expansion representations. *Journal of the Atmospheric Sciences*, **46**(12), 1664-1686.

Galbally, I.E. and G.I. Pearman (1988) Chemical processes and constituents in the atmosphere, In: *Meteorology and Physical Oceanography in Australia, Priorities in Research, Operations and Education*, edited by P.G. Baines. Australian Meteorological and Oceanographic Publication No.3, pp. 13-24.

Galbally, I.E., M.E. Cope, F. Carnovale, B.J. Cook and D.R. Hearn (1988) Modelling photochemical smog in the Latrobe Valley. *Clean Air*, **22**(4), 185-191.

Galbally, I.E., I.A. Weeks, S.T. Bentley, C.M. Elsworth and F. Carnovale (1988) The distribution of C_2 to C_{10} hydrocarbons in the Latrobe Valley during summer 1987/1988. *Clean Air*, **22**(4), 201-202.

Duffy, L., I.E. Galbally and M. Elsworth (1988) Biogenic NO_x emissions in the Latrobe Valley. *Clean Air*, **22**(4), 196-198.

Smith, C.J., J.R. Freney, P.M. Chalk, I.E. Galbally, D.J. McKenney and G.X. Cai (1988) Fate of urea nitrogen applied in solution in furrows to sunflowers growing on a red-brown earth: Transformations, losses and plant uptake. *Australian Journal of Agricultural Research*, **39**, 793-806.

Galbally, I.E. (1989) Factors controlling NO_x emissions from soils. In: *Exchange of trace gases between terrestrial ecosystems and the atmosphere: Report of the Dahlem Workshop on Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere*, Berlin, edited by M.O. Andreae and D.S. Schimel, Wiley, p. 23-37.

Galbally, I.E. and C. Johansson (1989) A model relating laboratory measurements of rates of nitric oxide production and field measurements of nitric oxide emission from soils. *Journal of Geophysical Research*, **94**(D5), 6473-6480.

Galbally, I.E. and G.W. Paltridge (1989) The ozone issue. In: *Disease and Society: A Resource Book*, edited by R. Dircks. Australian Academy of Science, p.1.9-1.11.

Smith, C.J., J.R. Freney, S.L. Chapman and I.E. Galbally (1989) Fate of urea nitrogen applied to irrigated wheat at heading. *Australian Journal of Agricultural Research*, **40**, 951-963.

Rosswall T., I.E. Galbally *et al.* (1989) What regulates production and consumption of trace gases in ecosystems: Biology or physicochemistry? In: *Exchange of Trace Gases Between Terrestrial Ecosystems and the Atmosphere: Report of the*

Dahlem Workshop on Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere, Berlin, edited by M.O. Andreae and D.S. Schimel, Wiley, p. 73–95.

Schimel D.S., I.E. Galbally *et al.* (1989) Priorities for an international research program on trace gas exchange In: *Exchange of trace gases between terrestrial ecosystems and the atmosphere: Report of the Dahlem Workshop on Exchange of Trace Gases between Terrestrial Ecosystems and the Atmosphere*, Berlin, edited by M.O. Andreae and D.S. Schimel, Wiley p. 321–331.

Cameron, M., I.E. Galbally, P. Manins, B. Sawford and D. Williams (1989) Status of air quality in Australia. Stage 1: Assessment of relevant data. CSIRO, Divisions of Atmospheric Research, Coal Technology, and Mathematics and Statistics. Report to DASETT.

Carnovale, M.E. Cope and I.E. Galbally (1989) The impact of anthropogenic and natural emissions on photochemical smog production in the Latrobe Valley. In: *Man and His Ecosystem: Proceedings of the Eighth World Clean Air Congress*. Amsterdam: Elsevier, 3, 407–412.

Galbally I.E. (1990) Editor: *The International Global Atmospheric Chemistry Programme Report*, Commission on Atmospheric Chemistry and Global Pollution of the International Association of Meteorology and Atmospheric Physics, 55pp.

Randall, P.J., J.R. Freney, C.J. Smith, H.J. Moss, C.W. Wrigley and I.E. Galbally (1990) Effect of additions of nitrogen and sulfur to irrigated wheat at heading on grain yield, composition and milling and baking quality. *Australian Journal of Experimental Agriculture*, **30**, 95–101.

Garratt, J.R. and M. Segal (1988) On the contribution of atmospheric moisture to dew formation. *Boundary-layer Meteorology*, **45**(3), 209–236.

Garratt, J.R. (1989) [Book Review] An Introduction to Boundary Layer Meteorology, by R.B. Stull. *Boundary-layer Meteorology*, **48**(4), 451–452.

Garratt, J.R. and R.A. Pielke (1989) On the sensitivity of mesoscale models to surface-layer parameterization constants. *Boundary-layer Meteorology*, **48**(4), 377–387.

Garratt, J.R. and B.F. Ryan (1989) The structure of the stably stratified internal boundary layer in offshore flow over sea. *Boundary-layer Meteorology*, **47**(1), 17–40.

Garratt, J.R., P.C. Howells and E. Kowalczyk (1989) The behaviour of dry cold fronts travelling along a coastline. *Monthly Weather Review*, **117**(6), 1208–1220.

Segal M., J.R. Garratt, G. Kallos and R.A. Pielke (1989) The impact of wet soil and canopy temperatures on daytime boundary-layer growth. *Journal of the Atmospheric Sciences*, **46**(24), 3673–3684.

Ye Z.J., M. Segal, J.R. Garratt and R.A. Pielke (1989) On the impact of cloudiness on the characteristics of nocturnal downslope flows. *Boundary-layer Meteorology*, **49**(1–2), 23–51.

Segal, M., W. Schreiber, G. Kallos, J.R. Garratt, A. Rodi, J. Weaver and R.A. Pielke (1989) The impact of crop areas in northeast Colorado on midsummer mesoscale thermal circulations. *Monthly Weather Review*, **117**(4), 809–825.

Garratt, J.R. (1990) The internal boundary layer — a review. *Boundary-layer Meteorology*, **50**(1–4), 171–203.

Garratt, J.R. and B.B. Hicks (1990) Micrometeorological and PBL experiments in Australia. *Boundary-layer Meteorology*, **50**, 11–29.

Garratt, J.R., A.B. Pittock and K. Walsh (1990) Response of the atmospheric boundary layer and soil layer to a high altitude, dense aerosol cover. *Journal of Applied Meteorology*, **29**(1), 35–52.

Ye Z.J., J.R. Garratt, M. Segal and R.A. Pielke (1990) On the impact of atmospheric thermal stability on the characteristics of nocturnal downslope flows. *Boundary-layer Meteorology*, **51**(1–2), 77–97.

Gillett R.W., G.P. Ayers and S.J. Mainwaring (1989) Source contributions to atmospheric aerosols using organic tracers. In: *Man and His Ecosystem: Proceedings of the Eighth World Clean Air Congress*, 3, 551–556.

Gillett R.W., G.P. Ayers and B.N. Noller (1990) Rainwater acidity at Jabiru, Australia, in the wet season of 1983/84. *Science of the Total Environment*, **92**, 129–144.

Goodman, H.S. and R.J. Francey (1988) $^{13}\text{C}/^{12}\text{C}$ and $^{18}\text{O}/^{16}\text{O}$ in baseline CO_2 , 1986. In: *Baseline Atmospheric Program (Australia)* 1986. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p 54–58.

Goodman, H.S. and R.J. Francey (1989) $^{13}\text{C}/^{12}\text{C}$ and $^{18}\text{O}/^{16}\text{O}$ in baseline CO_2 , 1986. In: *Baseline Atmospheric Program (Australia)* 1987. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p 29.

Gordon, H.B. and B.G. Hunt (1990) Rainfall perturbations induced by sea surface temperature anomalies. In: *The Role of Sea Surface Temperatures in Numerical Modelling of the Atmosphere*, BMRC Research Report No. 21, edited by J.D. Jasper, Bureau of Meteorology Research Centre, Melbourne, p.80–83.

Gras, J.L. (1988) Calibration in the Cape Grim condensation nucleus particle program. In: *Baseline Atmospheric Program (Australia)* 1986. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p 10–14.

Gras, J.L., G.P. Ayers, S. Bentley and R.W. Gillett (1988) Latrobe Valley aerosol and visibility — preliminary findings from the CSIRO study. *Clean Air*, **22**(4), 226–228.

Gras, J.L. (1989) Baseline atmospheric condensation nuclei at Cape Grim 1977–1987. *Journal of Atmospheric Chemistry*, **11**, 89–106.

Gras, J.L. (1989) Particles. In: *Baseline Atmospheric Program (Australia)* 1987. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.47–48.

Gras, J.L. and W.D. Jones (1989) Australian aerosol backscatter survey. *Applied Optics*, **28**(5), 852–856.

Gras, J.L. (1990) "Baseline" particle measurements in Southern Ocean air. In: *Proceedings of the International Clean Air Conference*, Auckland, Clean Air Society of Australia and New Zealand, p. 347–348.

Gras, J.L. and G.P. Ayers (1990) Marine phytoplankton and the global climate feedback — testing the hypothesis. *Australian Meteorological Magazine*, **38**(2), 93–98.

Gras, J.L., G.P. Ayers, R.W. Gillett and S.T. Bentley (1990) Regional visibility and aerosol properties in south-eastern Australia. In: *Proceedings of the Tenth International Clean Air Conference*, Auckland, Clean Air Society of Australia and New Zealand, p. 247–252.

Hendon, H.H., N.E. Davidson and B.W. Gunn (1989) Australian summer monsoon onset during AMEX 1987. *Monthly Weather Review*, **117**(2), 370–390.

Hendon, H.H., B.W. Gunn *et al.* (1989) The Australian summer monsoon circulation during AMEX Phase II. *Monthly Weather Review*, **117**(11), 254–257.

Hennessy, K.J. (1990) Regional climate change scenarios for Australia. In: *Proceedings of the IGBP Workshop 13 on Mathematical and Statistical Modelling of Global Change Processes*, Centre for Mathematical Analysis, ANU, Canberra, **25**, 113–135.

Hibberd, M.F. and J. Dohmann (1988) The anisotropy of grid-generated turbulence in dilute polymer solutions. In: *Proceedings of the Tenth International Congress on Rheology*. Australian Society of Rheology, **1**, 404–406.

Gieseckus, H. and M.F. Hibberd (1988) On the structure of turbulent flow of drag reducing fluids. In: *Progress and Trends in Rheology II*. Steinkopff, Darmstadt, p.15–16.

Hibberd, M.F. and B.L. Sawford (1989) A laboratory model of convection in the atmospheric boundary layer. In: *Proceedings of the Tenth Australasian Fluid Mechanics Conference*, Melbourne, Australia.

Hibberd, M.F. (1990). Report on meteorological data relating to pollution incidents at Middle Swan Primary School on 8th March 1990. A report to the Environmental Protection Authority of Western Australia. 15pp.

Hibberd, M.F. and B.L. Sawford (1990) A new saline laboratory model for studying dispersion in the convective boundary layer. In: *Proceedings of the Ninth Symposium on Turbulence and Diffusion*, AMS, Boston, USA.

Hirst, A.C. and D.S. Battisti (1989) Interannual variability in a tropical atmosphere-ocean model: Influence of the basic state, ocean geometry. *Journal of the Atmospheric Sciences*, **46**(12), 1687-1712.

Hirst, A.C., D.S. Battisti and E.S. Sarachile (1989) Instability and predictability in coupled atmosphere-ocean models. *Philosophical Transactions of the Royal Society of London*, **329**, 237-245.

Hirst, A.C. and K.M. Lau (1990) Intraseasonal and interannual oscillations in coupled ocean-atmosphere models. *Journal of Climate*, **3**, 713-725.

Holper, P.N. (1990) Agriculture in the greenhouse. *Trees and Natural Resources*, **32**(2), 24-27.

Holper, P.N. (1990) Depletion of the ozone layer. *Australian Refrigeration, Air Conditioning and Heating*, **44**(7), 31-34.

Holper, P.N. and W.J. Bouma (1990) The greenhouse effect: The basics. *Australian Science Mag*, **35**(2), 26-31.

Howells, P.A.C. and Ying-Hwa Kuo (1988) A numerical study of the mesoscale environment of a Southerly Buster event. *Monthly Weather Review*, **116**(9), 1771-1788.

Hughes, R.L. (1989) The hydraulics of local separation in a coastal current with application to the Kuroshio meander. *Journal of Physical Oceanography*, **19**(12), 1809-1820.

Hughes, R.L. (1990) Editor: *Oceanic Hydraulics*, Birkhauser, 177pp.

Hughes, R.L. (1990) On the general character of coastal flows. *Pure and Applied Geophysics*, **133**(4), 665-676.

Hughes, R.L. (1990) On the role of transients in trapping eastern boundary currents. *Dynamics of Atmospheres and Oceans*, **14**(5), 417-439.

Hunt, B.G. (1988) Perturbations to general atmospheric circulation caused by global change. In: *Global change: Proceedings of the Elizabeth and Frederick White Research Conference*, Canberra, Australian Academy of Science. p.93-97.

Hunt, B.G. (1989) Middle atmosphere response to solar and tropospheric forcing. *Solar-Terrestrial Energy Program: major scientific problems: Proceedings of a SCOSTEP symposium held during the XXVII COSPAR Plenary Meeting*, SCOSTEP Secretariat, p.111-165.

Hunt, B.G. (1989) Modelling past climate — techniques and results. In: *CLIMANZ 3: Proceedings of the Third Symposium on the Late Quaternary Climatic History of Australasia*. Melbourne, edited by T.H. Donnelly and R.J. Wasson. Canberra, Division of Water Resources, p. 1-3.

Hunt, B.G. and H.B. Gordon (1989) Diurnally varying regional climatic simulations. *International Journal of Climatology*, **9**(4), 331-356.

Hunt, B.G. and H.B. Gordon (1989) The problem of "naturally" occurring drought. *Climate Dynamics*, **3**(1), 19-33.

Hunt, B.G. (1990) A simulation of the gravity wave characteristics and interactions in a diurnally varying model atmosphere. *Journal of the Meteorological Society of Japan*, **68**(2), 145-161.

Jensen, J.B. and M.B. Baker (1989) A simple model of droplet spectral evolution during turbulent mixing. *Journal of the Atmospheric Sciences*, **46**(18), 2812-2829.

Raga, G.B., J.B. Jensen and M.B. Baker (1990) Characteristics of cumulus band clouds off the coast of Hawaii. *Journal of the Atmospheric Sciences*, **47**(3), 338-355.

Long, A.B. (1989) [Book Review] Precipitation — Process and Analysis, by Graham Sumner, Wiley & Sons, 1988. *Australian Meteorological Magazine*, **37**(2), 109-110.

Long, A.B., B.A. Campistron and A.W. Huggins (1990) Investigations of a winter mountain storm in Utah. Part I: Synoptic analyses, mesoscale kinematics, and water release rates. *Journal of the Atmospheric Sciences*, **47**, 1302-1322.

Sassen, K., A.W. Huggins, A.B. Long, J.B. Snider and R.J. Meitin (1990) Investigations of a winter mountain storm in Utah. Part II: Mesoscale structure, supercooled liquid water development, and precipitation processes. *Journal of the Atmospheric Sciences*, **47**, 1323-1350.

Manins, P.C. (1988) Atmospheric dispersion: observations and models; commentary. In: *Flow and Transport in the Natural Environment: Advances and Applications*, edited by W.L. Steffen and O.T. Denmead. Berlin: Springer-Verlag, p.377-380.

Manins, P.C. (1988) Meteorology and air quality of the Latrobe Valley. *Clean Air*, **22**(4), 132-137.

Manins, P.C. (1988) Guest Editor: Latrobe Valley AirShed Study Symposium. Special issue of *Clean Air*, **22**(4), 104pp.

Manins, P.C. and D. Jones (1988) The height of the nocturnal boundary layer in the Latrobe Valley, Victoria. *State Electricity Commission, Research and Development Report No. LO/88/004*.

Manins, P.C., J. Carras and D. Williams (1988) Plume rise in the Latrobe Valley. *Clean Air*, **22**(4), 151-153.

Hess, G.D. and P.C. Manins (1988) Research on local environmental processes. In: *Meteorology and Physical Oceanography in Australia: Priorities in Research, Operations and Education*, edited by P.G. Baines. Australian Meteorological and Oceanographic Society Publication No 3, p37-45.

Manins, P.C. (1989) Air quality impact analyses, air pollution alarm system. Assignment Report. WHO Regional Office for the Western Pacific. KOR/CEH/001/RB.

Manins, P.C. (1989) Assimilative capacity of the Latrobe Valley airshed for emissions from energy-related industrial activity. In: *Air Pollutants From Energy Industries: Scientific Basis of Standards and Research Needs*, edited by A.J. Jakeman, Centre for Resource and Environmental Studies, Australian National University p. 52-67.

Manins, P.C. (1989) A case study of plume impact on elevated terrain — model performance. *Clean Air*, **23**(2), 80-82.

Manins, P.C. (1989) [Consultancy Report] Kalgoorlie air quality control strategy. A report to Bond Gold (Australia). CSIRO Division of Atmospheric Research.

Manins, P.C. (1989) A meteorological curiosity of Melbourne, Australia. *Journal of the Korean Meteorological Society*, **25**(4), 289-295.

Manins, P.C. (1989) Model performance in the Latrobe Valley Airshed Study. *Clean Air*, **23**(2), 78-79.

Manins, P.C. (1989) Models for impact on air quality; the Latrobe Valley Airshed Study. In: *Man and His Ecosystem: Proceedings of the Eighth World Clean Air Congresses*, edited by L.J. Brasser and W.C. Mulder, Amsterdam, Elsevier, 4, 71-76.

Manins, P.C. (1989) Two air pollution problem areas in Australia. *Korean Journal of Sanitation*, **4**(2), 15-26.

Manins, P.C. (1989) [Book Review] Lectures on Air Pollution Modeling, edited by A. Venkatram and J. C. Wyngard. American Meteorological Society, Boston, 1989. *Australian Meteorological Magazine*, **37**(4), 232-233.

Manins, P.C. and B.L. Sawford (1989) [Consultancy Report] Review of air quality estimates for a proposed 600 MW power station at Hill River, Western Australia. A report to Steedman Science and Engineering. CSIRO Division of Atmospheric Research, 12 pp.

Manins, P.C. (1990) Pollutant dispersion in complex terrain: the Latrobe Valley example. In: *Proceedings of the International Clean Air Conference*, Auckland, Clean Air Society of Australia and New Zealand, p. 145-149.

Manins, P.C. (1990) Quality assurance manual of the CSIRO Division of Atmospheric Research wind tunnel for NATA certifications. CSIRO Division of Atmospheric Research. No. 1, 26pp.

Manins, P.C. (1990) Supplementary studies for Collie Power Station ERMP. A Report to State Energy Commission of Western Australia. 13 pp.

Manins, P.C. (1990) [Book Review] Air Pollution Control Manual of Continuous Emission Monitoring; Regulations and Procedures for Emission Measurement, 2nd revised edition, 1988. *Clean Air*, **24**(1), 8.

Manins, P.C. and W.L. Physick (1990) [Consultancy Report] Morning fumigation and the Gidji roaster. Report to Kalgoorlie Consolidated Gold Mines. CSIRO Division of Atmospheric Research, 7 pp.

Manins, P.C. and W.L. Physick (1990) [Consultancy Report] Morning fumigation events at Hill River. Report to Steedman Science & Engineering. CSIRO Division of Atmospheric Research, 22 pp.

Mansbridge, J.V., F.J. Robbins and P.J. Fraser (1988) Variation in measurements of methane, carbon dioxide and carbon monoxide from Cape Grim flask samples. In: *Baseline Atmospheric Program (Australia) 1986*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p. 27–35.

Mansbridge, J.V. and I.G. Enting (1990) Sensitivity studies in a two-dimensional atmospheric transport model. *CSIRO Division of Atmospheric Research Technical Paper No. 18*.

McGregor, J.L. and D.J. Abbs (1988) Modelling mesoscale effects in the Latrobe Valley with a nested model. *Clean Air*, **22**(4), 153–156.

McGregor, J.L. and F. Kimura (1989) Numerical simulation of mesoscale eddies over Melbourne. *Monthly Weather Review*, **117**(1), 50–66.

Hart, T.L. and J.L. McGregor (1990) Atmospheric general circulation simulations with the BMRC global spectral model: the impact of revised physical parameterizations. *Journal of Climate*, **3**(4), 436–459.

Mitchell, R.M. (1989) Atmospheric correction of vegetation indices using split pass AVHRR imagery. In: *Proceedings of Fourth AVHRR Users' Meeting*, Rothenburg, F.R. Germany, p. 153–156.

Mitchell, R.M., R.P. Cechet, P.J. Turner and C.C. Elsum (1990) Observation and interpretation of wave clouds over Macquarie Island. *Quarterly Journal of Royal Meteorological Society*, **116**(493), 741–752.

Moore, A.M. (1989) Aspects of geostrophic adjustment during tropical ocean data assimilation. *Journal of Physical Oceanography*, **19**, 435–461.

Moore, A.M. (1989) The assimilation of AXBT data into a layer model of the tropical Pacific ocean. *Dynamics of Atmosphere and Oceans*, **13**, 441–464.

Moore, A.M., V.T. Buchwald and M.E. Brewster (1989) A stokesian entry flow. *Quarterly Journal of Mechanical and Applied Mathematics*, **43**, 107–133.

Moore, A.M. (1990) Linear equatorial wave mode initialization in a model of the tropical Pacific Ocean: an initialization scheme for tropical ocean models. *Journal of Physical Oceanography*, **20**(3), 423–445.

O'Brien, D.M. and R.M. Mitchell (1988) Retrieval of surface wind speed and aerosol optical depth over the oceans from AVHRR. *Journal of Applied Meteorology*, **27**(12), 1395–1403.

O'Brien, D.M. (1989) A lower bound for the solution of the radiative transfer equation in finite clouds. *Journal of Quantitative Spectroscopy Radiative Transfer*, **42**, 551–556.

O'Brien, D.M. (1989) Measurement of atmospheric pressure from space. In: *Proceedings of the Fifth National Space Engineering Symposium*, Canberra, p.102–106.

O'Brien, D.M. and R.M. Mitchell (1990) Zones of feasibility for retrieval of surface pressure from observations of absorption in the A-band of oxygen. *Technical Report 19, CSIRO Division of Atmospheric Research*.

O'Brien, R. (1989) Seasonal variations between baseline and total dry bulb temperature measurements at Cape Grim. In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.26–28.

O'Brien, R. and P. Walford (1989) Data archive. In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.64–67.

Paltridge, G.W. (1989) Mesostat data as an index of fluctuations in Earth radiation budget on weekly and monthly time scales. *Atmosfera*, **2**(2), 125–129.

Paltridge, G.W. and J.W. Barber (1989) Monitoring grassland dryness and dryness potential in Australia with NOAA/AVHRR data. *Remote Sensing of Environment*, **25**(3), 381–394.

Paltridge G.W. and R.M. Mitchell (1990) Atmospheric and viewing angle correction of vegetation indices and grassland fuel moisture content derived from NOAA/AVHRR. *Remote Sensing of Environment*, **31**(2), 121–135.

Pearman, G.I. (1988) The changing composition of the global atmosphere with respect to the greenhouse gases. In: *Global Change. Proceedings of the Elizabeth and Frederick White Research Conference*, Australian Academy of Science, Canberra.

Pearman, G.I. (1988) Greenhouse gases: evidence for atmospheric changes and anthropogenic causes. In: *Global change: Proceedings of the Elizabeth and Frederick White Research Conference*, Canberra, Australian Academy of Science, p.84–92.

Pearman, G.I. (1988) Editor. *Greenhouse: Planning for Climate Change*, CSIRO Melbourne, 752 pp.

Pearman, G.I. (1988) Greenhouse gases: evidence for atmospheric changes and anthropogenic causes. In: *Greenhouse: Planning for Climate Change*, edited by G.I. Pearman. CSIRO Melbourne, p. 3–21.

Pearman, G.I., R.C. Harriss *et al.* (1988) Group report; How has the atmosphere already changed? In: *The Changing Atmosphere: Report of the Dahlem Workshop on the Changing Atmosphere*, Berlin, edited by S. Rowland and I.S.A. Isaksen, Wiley, p.201–216.

Pearman, G.I. (1989) The greenhouse effect: Global and Australian perspectives. In: *Proceedings of the Australian Institute of Energy Conference on Energy and the Greenhouse Effect*, Melbourne.

Pearman, G.I., N.J. Quinn and J.W. Zillman (1989) The changing atmosphere. *Search*, **20**(2), 59–65.

Pearman, G.I. *et al.* (1989) What anthropogenic impacts are recorded in glaciers? In: *The Environmental Record in Glaciers and Ice Sheets*, edited by H. Oeschger and C.C. Langway Jr., Wiley, p.269–286.

Pearman, G.I. (1990) The greenhouse effect — current research. In: *Proceedings of the 1990 Australian Coal Conference*, **2**, 17–26.

Pearman, G.I. (1990) The greenhouse effect — interfacing science and policy. *Search*, **21**(3), 101–106.

Pearman, G.I. (1990) Predictions of climatic change from best scientific models. In: *Global Climatic Change Issues for Australia*. Prime Minister's Science Council, Canberra 197 pp.

Physick, W.L. (1988) Mesoscale modelling of a cold front and its interaction with a diurnally heated land mass. *Journal of the Atmospheric Sciences*, **45**(21), 3169–3187.

Physick, W.L. (1988) [Review] Mesoscale modelling in complex terrain. *Earth Science Reviews*, **25**, 199–235.

Physick, W.L. and D.J. Abbs (1988) Particle dispersion by sea breezes in the Latrobe Valley. *Clean Air*, **22**, 147–149.

Physick, W.L. and D.J. Abbs (1988) A three-dimensional study of pollutant dispersion in a coastal valley. In: *Proceedings of a Workshop on Meteorology and Atmospheric Dispersion in a Coastal Area*, Roskilde, Denmark.

Physick, W.L. (1989) A numerical system for predicting air quality. *Clean Air*, **23**(3), 119–121.

Physick, W.L. and R.W. Arritt (1989) Formulation of the thermal internal boundary layer in a mesoscale model. II. Simulations with a level-2.5 turbulence closure. *Boundary Layer Meteorology*, **49**(4), 411–416.

Physick, W.L. and J.R. Garratt (1989) Incorporation of a forested lower boundary into a mesoscale model for studies of dry deposition over complex terrain. *Interim report. Contract*

agreement no. 28-C8-478 between Chisholm Institute of Technology, Melbourne and Rocky Mountain Forest and Range Experiment Station, Fort Collins, USA.

Physick, W.L., D.J. Abbs and R.A. Pielke (1989) Formulation of the thermal internal boundary layer in a mesoscale model. *Boundary Layer Meteorology*, **49**(1–2), 99–111.

Physick, W.L. (1990) Area averaging experiments involving the dry deposition of trace gases. *Final report*. Contract agreement No. 28-C8-478 between Chisholm Institute of Technology, Melbourne and Rocky Mountain Forest and Range Experiment Station, Fort Collins, USA.

Physick, W.L. and N.J. Tapper (1990) A numerical study of circulations induced by a dry salt lake. *Monthly Weather Review*, **118**(5), 1029–1042.

Hurley, P. and W.L. Physick (1990) Fumigation modelling — a Lagrangian particle approach. *Mathematics and Computers in Simulation*, **32**, 65–70.

Pittock, A.B. (1988) Actual and anticipated changes in Australia's climate. In: *Greenhouse: Planning For Climate Change*, edited by G.I. Pearman. CSIRO Melbourne, p.35–51.

Pittock, A.B. (1988) The atmosphere: Issues for conservationists. In: *Pre-Conference Readings*, Australian Conservation Foundation National Conference, Sydney, p.7.1–7.7.

Pittock, A.B. (1988) Climatic catastrophes: The local and global effects of greenhouse gases and nuclear winter. In: *Natural and Man-made Hazards*, edited by M.I. El-Sabh and T.S. Murty. Dordrecht, D. Reidel, p.621–633.

Pittock, A.B. (1988) The Greenhouse Effect: Its Impact and Implications for Energy Policy. In: *Workshop Report No. 26*, NERDDC, Department of Primary Industry and Energy, Canberra, Appendix II, p.5–6. Reprinted in *Building Economist*, **27**(4), 15–17.

Pittock, A.B. (1988) Priorities in climate research. In: *Meteorology and Physical Oceanography in Australia, Priorities in Research, Operations and Education*, edited by P.G. Baines, Australian Meteorological and Oceanographic Society, Publication No. 3, Melbourne, p. 3–12.

Pittock, A.B. (1988) Regional Climatic Change and its Impacts. In: *Global change: Proceedings of the Elizabeth and Frederick White Research conference*, edited by K.D. Cole, Australian Academy of Science, Canberra, p. 98–109.

Pittock, A.B. (1989) Der Treibhauseffekt: Eine australische Perspektive. In: *Das Ende des blauen Planeten?: der Klimakollaps: Gefahren und Auswege*, edited by P.J. Crutzen and M. Muller. Munchen, C.H. Beck, p.89–100.

Pittock, A.B. (1989) The effect of long-term climatic changes on water resources. In: *Proceedings of the National Workshop on Planning and Management of Water Resource Systems, Risk and Reliability*, Adelaide, edited by G.C. Dandy and A.R. Simpson, Australian Water Resources Council conference series; no. 17, p.124–140.

Pittock, A.B. (1989) Environmental changes and their effects on natural hazards. In: *Natural Hazards and Reinsurance: Seminar Proceedings*, Lidcombe, N.S.W., edited by J. Oliver and N.R. Britton, Sterling Offices (Australia) Limited and Disaster Management Studies Centre, Cumberland College of Health Sciences, p. 91–106.

Pittock, A.B. (1989) The environmental impact of nuclear war: policy implications. *Ambio*, **18**(7), 367–371.

Pittock, A.B. (1989) [Foreword] *Hotting Up*, by B.M. Crowley, Magistra Publishing Company, South Melbourne, p. vii–xi.

Pittock, A.B. (1989) The greenhouse effect: regional climate change and Australian agriculture. In: *Proceedings of the Fifth Australian Agronomy Conference*, Australian Society of Agronomy, p. 289–303.

Pittock, A.B. (1989) Environmental impacts on Australia of a nuclear war. *Ambio*, **18**, 395–401.

Pittock, A.B. (1989) Thoughts on the environment. *Antithesis*, **3**(1), 13–14.

Pittock, A.B. (1989) [Book Review] The View From Leningrad: Climate Shocks: Natural and Anthropogenic, by K. Kondratyev. Wiley: 1988. *Nature*, **337**(6206), 419.

Pittock, A.B. (1989) [Book Review] Societal Response to Regional Climatic Change: Forecasting by Analogy, edited by M.H. Galntz, 1988. *Bulletin of the American Meteorological Society*, **70**(9), 1150–1152.

Pittock, A.B., and K.J. Hennessy (1989) Regional impact of the greenhouse effect on Victoria. *First Annual Report*. Victorian Ministry of Planning and Environment, Melbourne, 14pp.

Pittock, A.B. and G.I. Pearman (1989) Too late for certainty. *Search*, **20**(2), 50–51.

Pittock, A.B., K. Walsh and J.S. Frederiksen (1989) General circulation model simulation of mild nuclear winter effects. *Climate Dynamics*, **3**(4), 191–206.

Pittock, A.B., J. Frederiksen, J.R. Garratt and K. Walsh (1989) Climatic effects of smoke and dust produced from nuclear conflagrations. In: *Aerosols and Climate*, edited by P.V. Hobbs and M.P. McCormick, Deepak Pub., Hampton, VA, p.395–410.

Pittock, A.B. (1990) The greenhouse effect: the question is when? *Forests and Timber*, **24**, 36–39.

Pittock, A.B. (1990) The greenhouse effect and energy policy. In: *Proceedings of the Fourth International Photovoltaic Science and Engineering Conference*, Sydney, p 5–12.

Pittock, A.B. (1990) [Report on Reports] Our changing planet: the FY 1990 research plan: the U.S. Global Change Research program; and its update Our changing planet: the FY 1991 U.S. Global Change Research Program. *Environment*, **32**(4), 25–28.

Platt, C.M.R. and Harshvardhan (1988) Temperature dependence of cirrus extinction: implications for climate feedback. *Journal of Geophysical Research*, **93**(D9), 11,051–11,058.

Platt, C.M.R. (1989) The role of cloud microphysics in high-cloud effects on climate change. *Nature*, **341**(6241), 428–429.

Platt, C.M.R., J.D. Spinharne and W.D. Hart (1989) Optical microphysical properties of a cold cirrus cloud: Evidence for regions of small ice particles. *Journal of Geophysical Research*, **94**(D8), 11,151–11,164.

Stone, R.S., G.L. Stephens, C.M.R. Platt and S. Banks (1990) The remote sensing of thin cirrus cloud using satellites, lidar and radiative transfer theory. *Journal of Applied Meteorology*, **29**, 353–363.

Plumb, R.A. and D. McConalogue (1988) On the meridional structure of long-lived tropospheric constituents. *Journal of Geophysical Research*, **93**(D12), 15,897–15,913.

Plumb, R.A. (1989) On the seasonal cycle of stratospheric planetary waves. *Pure and Applied Geophysics*, **130**(2/3), 233–242.

Plumb, R.A. and M. Ting (1989) Examples of the horizontal propagation of quasi-stationary waves. *Journal of the Atmospheric Sciences*, **46**(18), 2801–2811.

Post, D.A. and H.A. Bridgman (1990) Fogwater acidity and quality in South East Australia. In: *Proceedings of the International Clean Air Conference*, Auckland, edited by P. Gibson, Clean Air Society of Australia, p.233–238.

Prata, A.J. (1989) Observations of the 5-day wave in the stratosphere and mesosphere. *Journal of the Atmospheric Sciences*, **46**(15), 2473–2477.

Prata, A.J. (1989) Observations of volcanic ash clouds in the 10–12 μm window using AVHRR/2 data. *International Journal of Remote Sensing*, **10**(4/5), 751–761.

Prata, A.J. (1989) Radiative transfer calculations for volcanic ash clouds. *Geophysical Research Letters*, **16**(11), 1293–1296.

Prata, A.J. (1989) Thermal infrared radiometry: Calibration, distortion and resolution. In: *Proceedings of the Fifth FAO/UN/WMO/ESA Training course in Remote Sensing*, CSIRO Division of Water Resources, Canberra.

Prata, A.J. and I.J. Barton (1989) Retrieval of temperature and humidity inversions using TOVS, AVHRR and ATSR Radiiances. *Final report to the Defence Sciences and Technology Organisation*. Salisbury, South Australia, 22pp.

Prata, A.J., A.F. Pearce and C.R. Manning (1989) Comparison of NOAA/AVHRR-2 sea surface temperatures with surface measurements in coastal waters. *International Journal of Remote Sensing*, **10**(101), 37–52.

Prata A.J., R. Cechet, I.J. Barton and D.T. Llewellyn-Jones (1989) The along track scanning radiometer for ERS-1: Data simulation and scan geometry. *Proceedings of the Fourth European AVHRR Users' Meeting*, Rothenburg, FRG., 285–287.

Prata A.J., A.F. Pearce, J.B. Wells, P.T. Hick and J.M. Carrier (1989) Remote sensing applied to Western Australian shelf and slope waters. *Report to the Australian Marine Science and Technology Association*. 65pp.

Prata A.J., A.F. Pearce, J.B. Wells, P.T. Hick, J.C. Carrier and R.P. Cechet (1989) A satellite sea surface temperature climatology of the Leeuwin Current, Western Australia. *Report for the Marine Sciences and Technology Council*, 65pp.

Pearce, A.F. and A.J. Prata (1989) Mysteries of the Leeuwin current, *The Western Angler*, October/November Issue, 35–36.

Prata, A.J. (1990) Volcanic ash detection and air safety, *COSSA Report 024*, ACT, 54pp.

Prata, A.J. and J. B. Wells (1990) A satellite sensor image of the Leeuwin current, Western Australia. *International Journal of Remote Sensing*, **11**(1), 173–180.

Prata, A.J., R.P. Cechet, I.J. Barton and D.T. Llewellyn-Jones (1990) The along track scanning radiometer for ERS-1 — scan geometry and data simulation. *IEEE Transactions on Geoscience and Remote Sensing* **28**(1), 1–10.

Rayner, P. (1989) Palaeoclimate simulations with an energy balance model. In: *CLIMANZ 3: Proceedings of the Third Symposium on the Late Quaternary Climatic History of Australasia*. Melbourne, edited by T.H. Donnelly and R.J. Wasson. Canberra, Division of Water Resources, p. 14–22.

Jury M. and C. Reason (1989) Extreme subsidence in the Agulhas–Benguela air mass transition. *Boundary Layer Meteorology*, **46**, 35–51.

Robbins, F.J. and I.G. Enting (1989) Trajectory analysis of selected CO₂ data. II. In: *Baseline Atmospheric Program (Australia) 1987*. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.9–15.

Ryan, B.F. and R.C. O'Brien (1988) Boundary layer measurements of a convective rain band in tropical cyclone Irma. In: *Tropical Rainfall Measurements*, edited by J.S. Theon and N. Fugono. Deepak Publishing, p. 445–451.

Ryan, B.F. and K.J. Wilson (1988) The role of low-level cooling in a conceptual model of the Australian summertime cool change: implications for very-short-range forecasting. In: *Mesoscale analysis and forecasting incorporating "Nowcasting"*. Paris, European Space Agency, p.213–218.

Ryan, B.F., J.R. Garratt and W.L. Physick (1988) The prognosis of weather change lines over the ocean: the role of a reconnaissance aircraft. *Australian Meteorological Magazine*, **36**(2), 69–90.

Ryan, B.F., K.J. Wilson and E.J. Zipser (1989) Modification of the thermodynamic structure of the lower troposphere by the evaporation of precipitation ahead of a cold front. *Monthly Weather Review*, **117**(1), 138–183.

Sawford, B.L. and D.R. Hearn (1988) Primary air pollution in the Latrobe Valley: Non-reactive gas modelling. *Clean Air*, **22**(4), 167–172.

Sawford, B.L. (1989) Field measurements of power station atmospheric dispersion under convective conditions. *Progress Report, NERDDC Project 1136*. Department of Primary Industries and Energy, Canberra.

Sawford, B.L. (1989) Homogeneous turbulence. In: *Encyclopedia of Fluid Mechanics*, **8**, 191–223.

Sawford, B.L. (1989) [Book Review] Flow and Transport in the Natural Environment: Advances and Applications, edited by W.L. Steffen and O.T. Denmead (Springer Verlag, 1988). *Australian Meteorological Magazine*, **37**(4), 231–232.

Sawford, B.L. and F.M. Guest (1989) Lagrangian statistical simulation of the motion of heavy particles. In: *Proceedings of the Tenth Australasian Fluid Mechanics Conference*, Melbourne.

Carras, J.C., G. Ross, R. Simpson and B.L. Sawford (1989) Methods of source receptor modelling for air quality applications. In: *Air Pollutants From Energy Industries: Scientific Basis of Standards and Research Needs*, edited by A.J. Jakeman, CRES, ANU pp. 154–163.

Sawford, B.L. (1990) Field measurements of power station atmospheric dispersion under convective conditions. *Final Report, NERDDC Project 1136*. Department of Primary Industries and Energy, Canberra.

Sawford, B.L., S.A. Young, G. Patterson, E.F. Bradley, J.N. Carras, D.J. Williams, A.L. Lange, C.J. Thomson and N.J. Clark (1990) The Tarong power station convective atmospheric dispersion study. In: *Proceedings of the Ninth Symposium on Turbulence and Diffusion*. A.M.S. Boston.

Smith, I.N. (1989) Climatic conditions at the time of the last glacial maximum — general circulation model results for the Australasian region. In: *CLIMANZ 3: Proceedings of the Third Symposium on the Late Quaternary Climatic History of Australasia*. Melbourne. CSIRO Division of Water Resources, p. 33–41.

Ross, D.G., G. Lorimer, D.G. Fox and I.N. Smith (1989) Results of applying wind and dispersion models in complex topography. In: *Proceedings of the 82nd Annual Meeting and Exhibition of the Air and Waste Management Association*, Anaheim, California.

Smith, I.N. (1990) A comparison of model and observed net surface energy fluxes. In: *The Role of Sea Surface Temperatures in Numerical Modelling of the Atmosphere*, *BMRC Research Report No. 21*, edited by J.D. Jasper, Bureau of Meteorology Research Centre, Melbourne, p.119–123.

Tucker, G.B. (1988) Climate Modelling: how does it work? In: *Greenhouse: Planning For Climate Change*, edited by G.I. Pearman. CSIRO, Melbourne, p.22–34.

Tucker, G.B. (1988) Modelling in the International Geosphere–Biosphere Programme. In: *Global Change: Proceedings of the Elizabeth and Frederick White Research Conference*, Canberra, Australian Academy of Science. p.182–191.

Tucker, G.B. (1988) An overview of the Latrobe Valley Airshed Study. *Clean Air* **22**(4), 129–132.

Tucker, G.B. (1989) Laboratory modelling of air flow in the Sofia Valley. *Bulgarian Geophysical Journal*, **15**(1), 92–100.

Tucker, G.B. (1989) Meeting the challenge. In: *Greenhouse: What's To Be Done?* edited by K. Coghill. Leichhardt, N.S.W., Pluto Press in association with the Australian Fabian Society, p. 87–99.

Turner, P.J., R.M. Mitchell, C.C. Elsum and T.J. Davis (1988) The detection of bushfire and rain using the NOAA AVHRR radiometer. In: *Remote Sensing in Victoria*. National Science Centre Melbourne, Victoria p.83–93.

Turner, P.J. (1989) C-PIX — a library of routines for image manipulation. In: *Proceedings of Image Processing and the Impact of New Technologies Conference*. Edgecliff, N.S.W., Institution of Radio and Electronics Engineers, p. 269–272.

Turner, P.J. and C.C. Elsum (1989) A simple cloud detection scheme for use with NOAA AVHRR. In: *Proceedings of Image Processing and the Impact of New Technologies Conference*. Edgecliff, NSW: Institution of Radio and Electronics Engineers, p. 95–98.

Walsh, K. (1989) Greenhouse-induced climatic change in Australia. In: *Proceedings of the Greenhouse '88: Planning for Climate Change Conference*. South Australian Department of Environment and Planning.

Walsh, K. and A.B. Pittock, (1990) The sensitivity of a coupled atmospheric–oceanic model to variations in the albedo and absorptivity of a stratospheric aerosol layer. *Journal of Geophysical Research*, **95**(D7), 9941–9950.

Watterson, I.G. and A.F. Tuck (1989) A comparison of the longitudinal distributions of Antarctic stratospheric clouds and temperatures in 1987. In: *Preprints of a Symposium on the Role of the Clouds in Atmospheric Chemistry and Global Climate*, Anaheim, California, American Meteorological Society, p.205–206.

Watterson, I.G. and A.F. Tuck (1989) A comparison of the longitudinal distributions of polar stratospheric clouds and temperatures for the 1987 Antarctic spring. *Journal of Geophysical Research*, **94**(D14), 16511-16525.

Watterson, I.G., J.J. Margitan *et al.* (1989) Intercomparison of ozone measurements over Antarctica. *Journal of Geophysical Research*, **94**(D14), 16557-16569.

Weeks, I.A., I.E. Galbally, S.T. Bentley and C.M. Elsworth (1988) Atmospheric C₂ to C₁₀ hydrocarbons at Minniedale Road, Latrobe Valley during summer/autumn of 1986 and 1987. *Clean Air*, **22**(4), 199-200.

Almog, H., S.J. Mainwaring, I.A. Weeks, M. Cope and B. Cook (1988) Atmospheric fluorocarbons as indicators of air movements into and within the Latrobe Valley. *Clean Air*, **22**(4), 156-158.

Weeks, I.A., I.E. Galbally, P.J. Fraser and G. Matthews (1989) Comparison of the carbon monoxide standards used at Cape Grim and Aspendale. In: *Baseline Atmospheric Program (Australia)* 1987. Bureau of Meteorology in cooperation with CSIRO Division of Atmospheric Research, p.21-25.

Whetton, P.H. and J.T. Baxter (1989) The southern oscillation and river behaviour in south-eastern Australia. In: *CLIMANZ 3: Proceedings of the Third Symposium on the Late Quaternary Climatic History of Australasia*. Melbourne. CSIRO Division of Water Resources, p. 62-69.

Whetton, P.H. (1990) Relationships between monthly anomalies of Australian region sea-surface temperature and Victorian rainfall. *Australian Meteorological Magazine*, **31**(1), 31-41.

Whetton, P.H. (1990) Relationships between monthly anomalies of sea-surface temperature and mean sea level pressure in the Australian region. *Australian Meteorological Magazine*, **31**(1), 17-30.

Murphy, J.O. and P.H. Whetton (1990) A re-analysis of a tree ring chronology from Java. In: *Proceedings of the Koninklijke Nederlandse Akademie van Wetenschappen, Ser.B*, **92**, 241-257.

CONFERENCES

Overseas conference presentations

Conferences provide an important means by which Divisional scientists present and explain the work they are doing. In addition, there is the opportunity for important contact and interaction with colleagues from other organisations.

A major effort was made for the 59th ANZAAS Congress, held in Hobart in February 1990. The theme was "Global Change and the Southwest Pacific". Many presentations were made by members of the Division, including an introductory address by the Chief, Dr Brian Tucker. The Liversidge Lecture, entitled "The Greenhouse Effect: Interfacing Science and Policy" was delivered by Dr Graeme Pearman, the Division's Assistant Chief.

The following is a list of overseas conference presentations. 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.

1988

Environmental Effects of Nuclear War: Scientific Consensus and Global Policy Implications, Stockholm, Sweden, 20–22 August

Pittock, A.B. - Environmental impacts on Australia of a nuclear war
Pittock, A.B. - The environmental impact of nuclear war: policy implications

Workshop on Wildfire Severity and Global Climatic Change, Boulder, Colorado, USA, 28 September – 1 October

Beer, T. - Australian bushfire danger under changing climatic regimes

New Zealand Meteorological Service Annual Scientific Conference, Wellington, New Zealand, 4–6 October
Abbs, D.J. - Wind field modelling and pollutant transport for the Latrobe Valley

Interaction of the Global Carbon and Climate Systems, Lake Arrowhead, California, USA, 24–28 October

Enting, I.G. - Detecting departures from steady-state oceanic uptake of CO₂
Francey, R.J. and P.P. Tans - Oxygen-18 in atmospheric CO₂

Workshop on Meteorology and Atmospheric Dispersion in a Coastal Area, Roskilde, Denmark, 26–28 October

Physick, W.L. and D.J. Abbs - A three-dimensional study of pollutant dispersion in a coastal valley

Workshop on International Cooperation in Atmospheric Research Aircraft, Boulder, Colorado, USA, 2–3 November

Ryan, B.F. - The CSIRO F27 research aircraft
Ryan, B.F. - Allocating flight time on research aircraft and allocating use of other facilities

1989

Dahlem Workshop on Exchange of Trace Gases Between Terrestrial Ecosystems and the Atmosphere, Berlin, 19–24 February

Galbally, I.E. - Factors controlling NO_x emissions from soils
Galbally, I.E. *et al.* - What regulates production and consumption of trace gases in ecosystems: biology or physicochemistry?
Galbally, I.E. *et al.* - Priorities for an international research program on trace gas exchange

Geophysical Monitoring for Climatic Change Annual Meeting, Boulder, Colorado, USA, 8–9 March

Fraser, P.J. - Chloroform and methylchloride measurements at Cape Grim

Workshop on Remote Sensing for Land and Sea Resource Surveys and Evaluation in the Pacific: Applications, Co-ordination and Training, Port Vila, Vanuatu, 7–11 April
Dilley, A.C. - The CSIRO System for Interactive Data Analysis (CSIDA): a system for acquiring, processing and displaying meteorological satellite data

International Conference on Global and Regional Environmental Atmospheric Chemistry, Beijing, China, 3–10 May

Galbally, I.E., C.P. Meyer, C. Johansson, J.R. Freney, C.J. Smith, S.L. Chapman and L. Duffy - Emission of nitrogen oxides (NO_x) and related nitrogen transformations in winter irrigated wheat fertilized with urea

Conferences and Workshops supported by the Division

International Conference on Tropical Meteorology, Brisbane, 4–8 July 1988
Convener H. Hendon and D. Karoly

International Global Atmospheric Chemistry (IGAC) Workshop, Benalla, Victoria, 7–11 November 1988
Convener I. Galbally

The Scientific Application of Baseline Observations of Atmospheric Composition, Aspendale, 14–17 November 1988
Convener R.J. Francey

Parameterization of Radiative Processes, Aspendale, 15 June 1989
Convener C.M.R. Platt

Bushfire Meteorology and Dynamics, Canberra, 28–29 September 1989
Convener T. Beer

IGBP Planning Workshop on Sea-level Change and the Australian Coastline, Aspendale, 2–3 October 1989
Convener A.B. Pittock

Remote Sensing in Meteorology and Climatology, Aspendale, 10 October 1989
Convener C.M.R. Platt

Galbally, I.E., I.A. Weeks, S.T. Bentley, F. Carnovale and M.E. Cope - Atmospheric C₂ to C₁₀ hydrocarbons and ozone production in the Latrobe Valley, Australia

Fifth WMO Scientific Conference on Weather Modification and Applied Cloud Physics, Beijing, China, 8-12 May

Huggins, A.W., A.B. Long and B. Campistron - The impact of mesoscale precipitation bands on liquid water and precipitation efficiency in a winter mountain storm in Utah
Long, A.B. - The Melbourne winter storm cloud seeding experiment for urban water supply augmentation

Eighteenth Conference on Hurricanes and Tropical Meteorology, San Diego, California, USA, 16-19 May
Barnes, G.M., E. Zipser and B.F. Ryan - Rainband structure in developing tropical cyclone Irma

Fifth International TOVS Study Conference, Toulouse, France, 24-28 July

Prata, A.J. and I.J. Barton - Retrieval of inversions from TOVS, AVHRR and simulated ATSR radiances

WCRP Workshop on Planetary Boundary-Layer Modelling, ECMWF, Reading, England, 14-16 August

Garratt, J.R. - The sensitivity of large-scale models to PBL and land-surface parameterisations
Garratt, J.R. - Representation of the land-surface: Vegetation and sub-grid variability

Fourth European AVHRR Users' Meeting, Rothenburg, Germany, 4-8 September

Mitchell, R.M. - Atmospheric correction of vegetation indices using split pass AVHRR imagery
Prata, A.J., R. Cechet, I.J. Barton and D.T. Llewellyn-Jones - The along track scanning radiometer for ERS-1: Data simulation and scan geometry

Eighth World Clean Air Congress, The Hague, Holland 11-15 September

Manins, P.C. - Models for impact on air quality - The Latrobe Valley AirShed Study

Third International CO₂ Meeting, Hinterzarten, Germany, 16-20 October

Enting, I.G. - Kalman filtering in the analysis of CO₂ data
Enting, I.G., J.V. Mansbridge and R.J. Francey - Detecting the role of terrestrial biota from the atmospheric CO₂ record
Francey, R.J. and P.P. Tans - Global variations in ¹⁸O of atmospheric CO₂
Levin, I., V. Hesshaimer, R. Glockler, B. Kromer, K.O. Munnich and R.J. Francey - Radiocarbon in atmospheric CO₂: global distribution and trends
Pearman, G.J., I.G. Enting, R.J. Francey and J.V. Mansbridge - Possible oceanic biota effects on atmospheric CO₂ distribution in the southern hemisphere

Third International Conference on Southern Hemisphere Meteorology & Oceanography, Buenos Aires, Brazil, 13-17 November

Allan, R.J. and J.I. Pariwono - Ocean-atmosphere interactions in low latitude Australasia
Baines, P.G. - Topographic effects on the mean tropospheric flow pattern around Antarctica
Baines, P.G. and K. Fraedrich - Topographic effects on the mean tropospheric flow pattern around Antarctica

Cai, W. - Equatorial undercurrent in a revised layered numerical model

Orlanski, I., M. Marino, C. Menendez and J. Katzfey - The role of cyclones in the daily variability of Antarctic ozone
Reason C. and J. Jury - Aspects of the forcing, structure and propagation of the coastal lows of Southern Africa
Jury, M. and C. Reason - Subsidence in the Angulhas-Benguela transition zone arising from a reversal of heat fluxes

Intergovernmental Panel on Climate Change Meeting, Cambridge, Massachusetts, USA, 18-20 November
Fraser, P.J. - Carbon monoxide

Fourth Latin American Symposium on Remote Sensing, Bariloche, Argentina, 19-26 November

Dilley, A.C., C.C. Elsum, P.J. Turner and R.M. Mitchell - Australian AVHRR reception and analysis systems and some research and development activities

1990

Scope Workshop on Trace Gas Exchange in a Global Perspective, Sigtuna, Sweden, 19-23 February

Galbally I.E. - Tropical land use and trace gas emissions
Galbally I.E., C.P. Meyer, C. Johansson, J.R. Freney, C.J. Smith, R.R. Sherlock, S.L. Chapman and L. Duffy - Emission of nitrogen oxides (NO_x) and related nitrogen transformations in winter irrigated wheat fertilized with urea

Tropical Ozone and Atmospheric Change Conference, Penang, Malaysia, 20-23 February

Whetton, P.H. and A.B. Pittock - The greenhouse effect, climate change and sea-level rise

International Clean Air Conference, Auckland, New Zealand, 25-30 March

Gras, J.L. - "Baseline" particle measurements in Southern Ocean air
Gras, J.L., G.P. Ayers, R.W. Gillett and S.T. Bentley - Regional visibility and aerosol properties in south-eastern Australia
Manins, P.C. - Pollutant dispersion in complex terrain: the Latrobe Valley example
Post, D.A. and H.A. Bridgman - Fogwater acidity and quality in South East Australia

Fourth International Meeting on Statistical Climatology, Rotorua, New Zealand, 27-31 March

Beer, T. - Rainfall as a fractal process

International Meeting on Global Climate Change, Rome, Italy, 23-25 April

Hunt, B.G. - Australian research and response to the greenhouse effect

Ninth Symposium on Turbulence and Diffusion, Roskilde, Denmark, 30 April - 3 May

Hibberd, M.F. and B.L. Sawford - A new saline laboratory model for studying dispersion in the convective boundary layer
Sawford, B.L., S.A. Young, G. Patterson, E.F. Bradley, J.N. Carras, D.J. Williams, A.L. Lange, C.J. Thomson and N.J. Clark - The Tarong power station convective atmospheric dispersion study

TRACER Meeting, Virginia Beach, Virginia, USA, 2-3 May

Fraser, P.J. - Carbon monoxide measurement: Calibration and inter-laboratory comparison

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P.J. Turner BSc(Hons) PhD

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* Joined the Division during the reporting period 1988-1990

