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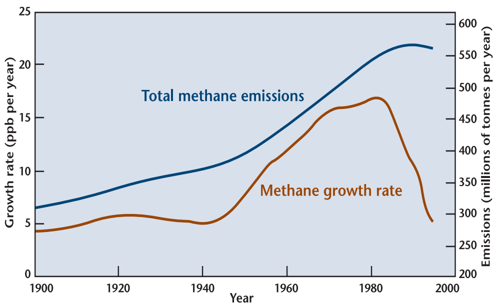
Global methane rise slows

During the past 200 years, atmospheric concentrations of methane have increased dramatically. Methane concentration now averages more than 1700 parts per billion, compared to 700 parts per billion at the end of the 18th century.

But while methane levels are still increasing, they are doing so more slowly than they were between 1960 and 1980, suggesting methane emissions are stabilising, says Mr David Etheridge.

Mr Etheridge combined direct measurements of methane levels in the atmosphere from the Cape Grim Baseline Air Pollution Station in Tasmania with data from ice cores in Antarctica going back 1000 years. His findings have been published in the *Journal of Geophysical Research*.

David Etheridge in Antarctica collecting air samples for analysis



Red line: The growth rate of the global mean concentration of atmospheric methane this century.

Blue line: The annual methane emissions to the atmosphere that explain the observed trends in concentration.

Methane levels were fairly stable up until the industrial revolution 200 years ago, explains Mr Etheridge. This suggests that human activities such as burning of biomass, fossil fuel exploration and distribution, rice farming, livestock and landfills were the main source of the increase.

'The slowdown in methane growth is good news, but we don't know exactly why it's happening yet. The next thing is to try and locate which of the sources have slowed.'

One possibility is that oil and gas technology has become more efficient over the past 20 years and reduced the amount of methane leakage, suggests Mr Etheridge.

However, the slower rate of increase in methane levels is no cause for complacency about human contributions to global warming. 'Until we know what the sources are, we don't know whether it's just a temporary perturbation.'

The Cape Grim Baseline Air Pollution Station is managed jointly by the Bureau of Meteorology and CSIRO. The Australian Antarctic Division supplies CSIRO with ice cores for analysis. ANSTO, and NIWA in New Zealand, are collaborating on sample collection and isotope measurements.

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Australia faces a significant air quality challenge, but it is largely because of indoor rather than outdoor pollutants, believes Dr Graeme Pearman, Chief of CSIRO Atmospheric Research.

Indoor air quality our next challenge

'We have made major progress in tackling air pollution problems,' says Dr Pearman. 'But the challenge now for Australia is to consider total air quality, not just the quality of air outside our homes, offices and cars.'

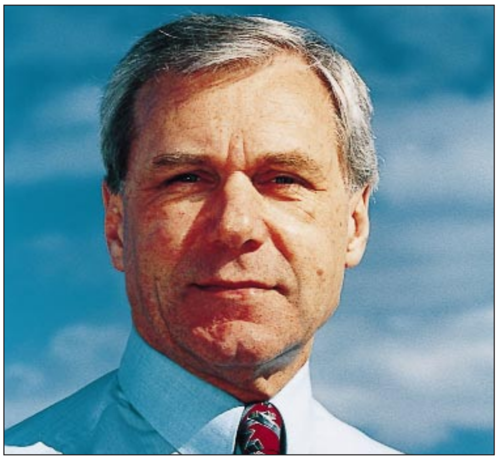
'For many of us, our main exposure to air pollutants will be when we are indoors, such as at home, in the workplace or in entertainment venues.'

Australians on average spend about ninety-five percent of their time indoors and many pollutants occur at higher concentrations indoors than outdoors because of the materials and appliances used in buildings.

'The ideal objective is to measure "individual exposure" to pollutants. That is, a measure of the actual exposure that people have to air pollutants during their daily routines, rather than measures of pollution at fixed locations,' says Dr Pearman.

'During the past decade, we have made major advances throughout Australia in improving the air that we breathe. Industry has generally taken a very responsible role in reducing pollution emissions.'

'Coupled with significant reductions in air pollution brought about by catalytic converters in motor vehicles, levels of pollutants such as carbon monoxide, oxides of nitrogen and hydrocarbons in urban air are dropping in many Australian cities.'



Dr Graeme Pearman

'We commend the low concentrations set by the National Environment Protection Measure (NEPM) for Ambient Air Quality for fine particles, announced by the National Environment Protection Council of Environment Ministers, especially as these particles have been shown to damage health,' says Dr Pearman. 'This may keep down fine particle levels in urban areas.'

The NEPM sets out maximum desirable concentrations for a range of pollutants, as well as maximum allowable exceedence targets to be achieved within ten years. Included in the Measure for Ambient Air Quality are carbon monoxide, nitrogen dioxide, photochemical oxidants (as ozone), sulfur dioxide, lead and particles as PM10. The Measure also specifies the way in which each pollutant should be measured and the measuring period.

'I especially congratulate the National Environment Protection Council, its Chairman, Senator Robert Hill, and the Chair of the Project Team that developed the NEPM for the Council, Dr Brian Robinson from the Victorian EPA, on their role during the past decade in helping to develop national uniform standards for air quality through the NEPM,' says Dr Pearman.

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New look at aerosol's impact on climate

Leon Rotstayn

When fossil fuels burn they produce tiny particles known as aerosol. Atmospheric aerosol are believed to exert a cooling effect on climate that is partially offsetting warming due to the enhanced greenhouse effect.

Dr Leon Rotstayn, studying the impact of aerosol on clouds

The 'direct' effect of aerosol has been studied most extensively. This is the white haze of pollution that is noticeable in the heavily industrialised areas of the northern hemisphere, and to a lesser extent over Melbourne and Sydney on high pollution days. This haze of small particles reflects some of the incoming sunlight back to space, and can have a small, but significant, cooling effect on climate.

Aerosol also affect the properties of clouds, because cloud droplets preferentially form on small particles or 'nuclei', rather than in completely clean air. The clouds that form in polluted air therefore contain more droplets than those that form in relatively clean air. So, the available amount of water is distributed over a larger number of droplets, which are smaller than those in clouds that form in cleaner air. The climatic effect of these changes in cloud properties is called the 'indirect' aerosol effect.

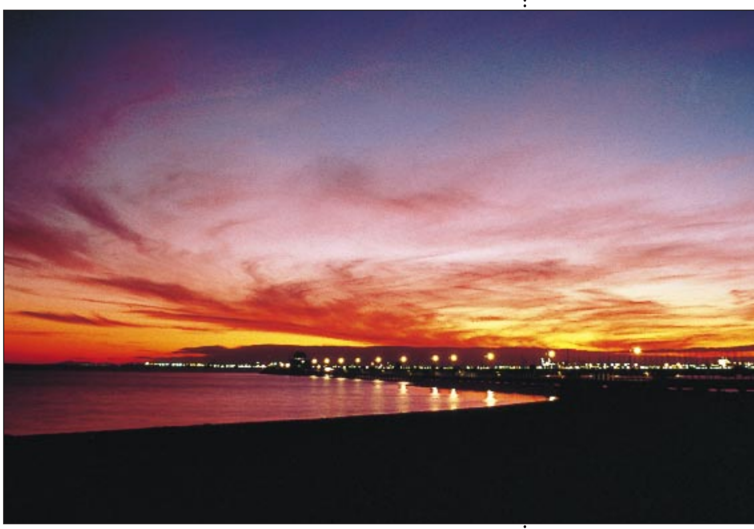
Recent research has suggested that the indirect aerosol effect is exerting a cooling influence that may be stronger than that due to the relatively well studied direct aerosol effect.

One reason for this cooling effect is that the clouds that form in polluted air are brighter than those that form in relatively clean air, so that they reflect more sunlight back to space.

A second reason for cooling is that in clouds comprising small droplets, more collisions are required for them to grow sufficiently large to form raindrops. This means that pollution suppresses rain formation and causes the clouds to persist for longer, thus further increasing the amount of sunlight reflected back to space. This is called the cloud-lifetime effect.

I have been using the CSIRO climate model to assess the importance of the indirect aerosol effect on our climate, including the cloud-lifetime effect. Until very recently, the cloud-lifetime effect had not been included in climate models.

My research suggests that the indirect aerosol effect becomes quite large when the cloud-lifetime effect is included in addition to the effect on cloud brightness. In fact, the indirect aerosol effect may be strong enough to be substantially offsetting the warming due to the enhanced greenhouse effect, and the sum of the two effects may even give a net cooling in some regions.



Does this mean that there is no need to be concerned about global warming? The answer is no, because the cooling effect of aerosol is largely restricted to the more polluted areas, whereas the greenhouse gases are well mixed throughout the entire atmosphere.

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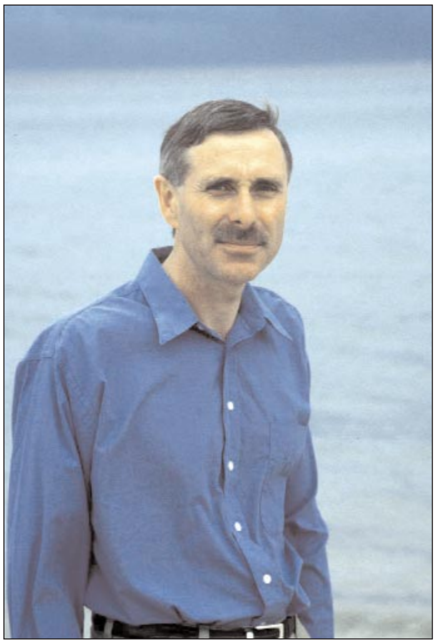
A model El Niño event

El Niño is a warming of the equatorial eastern Pacific Ocean that often leads to droughts over eastern Australia. La Niña is El Niño's wet sister, associated with cooling in the equatorial eastern Pacific, frequently causing wet conditions over eastern Australia.

If you are a researcher delving into the causes and consequences of El Niño and La Niña, you will spend much of your working day pondering the balmy conditions in the equatorial Pacific Ocean.



Dr Stephen Wilson, improving the way in which ocean models represent El Niño

Dr Stephen Wilson is a member of the Climate Modelling Program at CSIRO Atmospheric Research. During the past year or so, Dr Wilson has been working on a problem that has been long perplexing ocean modellers — how to simulate realistically the rapid drop in temperature that occurs in the equatorial eastern Pacific Ocean at depths of around 50–200 metres.

Typically, in this depth range, known as the thermocline, temperatures decrease sharply with increasing depth. For El Niño modelling it is important that the model captures this and that temperatures change sharply and realistically from 20°C to 15°C between 50–100 metres depth.

While ocean general circulation models have successfully reproduced the broad patterns of Pacific Ocean surface warming and cooling associated with El Niño and La Niña events, they have not been able to simulate the sharp thermocline and they have not been able to reproduce strong El Niño and La Niña events.

'Without a sharp thermocline, ocean models can't properly simulate the strong El Niños that were a feature of our climate during the early- to mid-1990s,' explains Dr Wilson.

Only when the sharp thermocline is correctly reproduced can the growth and decay of El Niño and La Niña be accurately predicted.

To solve the thermocline problem in his ocean model, Dr Wilson had to make a major change.

He had to devise a new mathematical representation of the way in which water mixes in the upper 350 metres of the ocean. Unfortunately, this did not fix the thermocline. It soon became clear to Dr Wilson that there was another problem.

This problem arises from the fact that many researchers restrict their models to the crucial region of the Pacific Ocean, between 20°N and 20°S. Without such a restriction, the models would require excessive computing power.

Dr Wilson found inaccuracies with the way in which ocean models transport heat at the northern and southern boundaries so he modified his model to improve these heat transports. With this problem fixed, 'suddenly, everything worked: the thermocline became sharp and the El Niño events became stronger'.

'We now have a more physically correct approach, giving one of the first general circulation models to accurately generate a strong El Niño and La Niña cycle,' says Dr Wilson.

Dr Wilson's research is now playing a critical role in CSIRO's development of a sophisticated global, coupled atmospheric–ocean model to be used for El Niño predictions.

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BRIEFS

Urban methane release

Many Melbourne residents endured a week of cold showers last year when an explosion at the city's gas supply plant led to severe restrictions.

The Division made the most of Melbourne's difficulties by examining how the gas supply disruption affected urban methane release. Scientists were keen to discover the relative contributions of emission sources, such as landfills, waste-water treatment and natural gas leakage.

Researchers collected air samples from an aircraft flight downwind of the city. Despite the gas shut-down, methane was clearly being emitted — the concentration was about two per cent above that of clean air. Scientists at Cape Grim, in north-western Tasmania, also collected air samples carried from Melbourne to the observatory by northerly winds.

Shortly, the air samples will be sent to other laboratories for further isotopic analysis. Then measurements will be compared with those from similar experiments conducted in times of normal gas supply. The expected result: a more comprehensive assessment of typical urban emissions of this important greenhouse gas.

Climate change in NSW

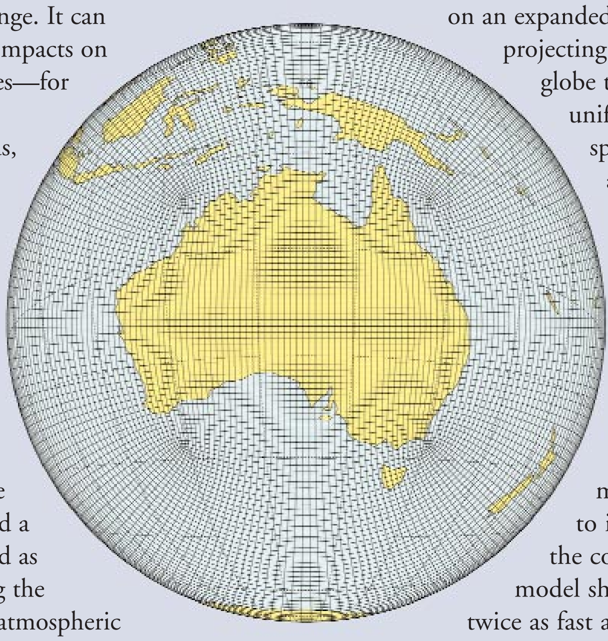
The Division has recently supplied the NSW Environment Protection Authority with a report detailing scenarios of climate change for the State. By 2050, NSW is likely to become 0.5–2.7°C warmer, with 10–50% more summer days over 35°C, and 20–100% fewer frosty winter days.

Rainfall is likely to increase in summer and autumn and decrease in winter and spring. The number of spring droughts is likely to double throughout NSW, except in the south-east. The number of wet summers, autumns and winters may double in some areas. Extreme daily rainfall is likely to become more intense and more frequent.

Zooming in on climate

A new CSIRO computer modelling technique offers close-up simulations of the regional effects of climate change. It can investigate potential impacts on different climate zones—for instance, Western Australia's wheat fields, or south-east Australia's cool temperate fruit region.

For more than four decades the world's global weather computing simulations (and more recently, climate simulations) have used a latitude/longitude grid as framework for solving the equations describing atmospheric dynamics. Such systems have superfluous resolution where latitude and longitude lines converge at the poles.



Dr John McGregor is now refining a high-resolution climate modelling technique based on an expanded cubic grid created by projecting a cube onto the globe to allow more uniform modelling of a spherical surface. Its ability to 'zoom' from large scale to close-up gives great potential for climate change studies.

The new approach is known as a 'conformal-cubic model'. In addition to its zooming abilities, the conformal-cubic model should run about twice as fast as the current CSIRO climate model as it can use longer time-steps.

Driving towards a cleaner future

Brad Collis

The Toyota Prius, one of a number of hybrid cars now available.

Australian scientists are developing the first prototype of a hybrid-electric car. The hybrid car will be a standard family-sized car with an internal combustion engine generating electricity, which in turn provides the motive power.

The hybrid car project is being funded by a consortium of Federal and State Government departments, the Energy Research Corporation, CSIRO and Market Australia who are contributing $23 million. Industry is injecting a total of $13.5 million.

The new car, to be paraded before the world at the 2000 Olympics, is aimed at demonstrating the viability and depth of Australian technology in the automotive sector as European, American and Japanese car makers begin looking seriously at new clean-energy technologies.

The car is being built by a leading car maker in Melbourne and will have a small four-cylinder engine running at constant speed to generate electricity either for batteries or capacitors that will power an electric motor on each wheel.

One of the project's initiators, Dr Graeme Pearman, says the car will be a revolutionary step forward in reducing greenhouse emissions and improving energy efficiency.

The hybrid electric car will have the same performance and range as a conventional car. The output of the combustion engine will simply be being put to a more efficient and cleaner use — generating electricity rather than powering the car.

'Energy management is the key,' says Dr Pearman.

'The electric motors driving the four wheels will actually be able to retrieve energy released when braking, or during turning when each wheel is operating at different speeds. Controlling and distributing this energy for maximum efficiency is the scientific challenge.'

Dr Pearman points out that the Dutch-based Shell oil company is one of the first multi-national fuel companies to grasp the likely speed of change, recently signalling its plans over the next 20 years to reinvent itself as an energy company rather than an oil company.

Dr Pearman says that the hybrid car is just one of a number of exciting developments now emerging in the climate change debate as opinions become less polarised and community awareness of the issues increases.

'The smart companies know that carbon emission is an issue that has to be a part of their business planning.'

'There is a growing relationship between trade and greenhouse performance and Australian companies have to be aware of that. Many are already positioning themselves for trade options and credits by offsetting their carbon production with investment in forest plantations.'

'Companies are coming to us for help with farm forestry, vegetation reserves and technical fixes such as dumping carbon dioxide back into depleted gas and oil fields.'

'Similarly, while planting trees may only delay carbon dioxide from entering the atmosphere for a decade, it's a decade closer to solar and other renewables becoming the main energy sources.'

Dr Pearman says the scientific challenge is being able to prove the changes in land and energy use are having an influence on the atmosphere.

Dr Pearman says the most heartening development over the past 12 months has been the closing gap between the once polarised forces in the greenhouse debate: 'Environmentalists are realising that not every business is out to destroy the natural environment, while those in industry are accepting that changes to energy production and use doesn't mean going back to primitive industrial systems or living conditions.'

'Instead, there's much more awareness that the changes required should bring many advances — industrially, socially and economically.'

Selected publications

These are a few of the more than 100 papers published by staff of CSIRO Atmospheric Research during the past six months. For a full list of our publications, visit http://www.dar.csiro.au/pub/services/library/pubsearch.html.

Ayers, G. P., Keywood, M. D., Gillett, R. W., Manins, P. C., Malfroy, H., and Bardsley, T. (1998). Validation of passive diffusion samplers for SO_2 and NO_2. *Atmospheric Environment,* **32** (20): 3587–3592.

Francey, R. J., Steele, L. P., Langenfelds, R. L., and Pak, B. C. (1998). High precision long-term monitoring of radiatively active and related trace gases at surface sites and from aircraft in the Southern Hemisphere atmosphere. *Journal of the Atmospheric Sciences,* **56** (2): 279–285.

Garratt, J. R., Prata, A. J., Rotstayn, L. D., McAvaney, B. J., and Cusack, S. (1998). The surface radiation budget over oceans and continents. *Journal of Climate,* **11** (8): 1951–1968.

O'Brien, D. M. (1998). Monte Carlo integration of the radiative transfer equation in a scattering medium with stochastic reflecting boundary. *Journal of Quantitative Spectroscopy and Radiative Transfer,* **60** (4): 573–583.

Pittock, A. B., Allan, R. J., Hennessy, K. J., McInnes, K. L., Suppiah, R., Walsh, K. J. E., Whetton, P. H., McMaster, H., and Taplin, R. (1999). Climate change, climatic hazards and policy responses in Australia. In: *Climate, change and risk.* T. E. Downing, A. A. Olsthoorn, and Tol. R. S. J. (editors). New York: Routledge. p. 19–59.

Prata, A. J., Grant, I. F., Cechet, R. P., and **Rutter, G. F.** (1998). Five years of shortwave radiation budget measurements at a continental land site in southeastern Australia. *Journal of Geophysical Research,* **103** (D20): 26093–26106.

Smith, I. N. (1998). Estimating mass balance components of the Greenland ice sheet from a long-term GCM simulation. *Global and Planetary Change,* **20** (1): 19–32.

Hennessy, K.J., Suppiah, R. and Page, C.M. (1999): Australian rainfall changes, 1910–1995. *Aust. Met. Mag.* **48**, 1–13.

Walsh, K. J. E., and **Pittock, A. B.** (1998). Potential changes in tropical storms, hurricanes, and extreme rainfall events as a result of climate change. *Climatic Change,* **39** (2–3): 59–73.

Wang, Y. P., Rey, A., and Jarvis, P. G. (1998). Carbon balance of young birch trees grown in ambient and elevated atmospheric CO_2 concentrations. *Global Change Biology,* **4** (8): 797–807.

Watterson, I. G., Dix, M. R., and Colman, R. A. (1998). A comparison of present and doubled CO_2 climates and feedbacks simulated by three general circulation models. *Journal of Geophysical Research,* **104** (D2): 1943–1956.

During October and November of 1998, CSIRO, MRI (Japan) and BMG (Indonesia) conducted a joint aircraft and ground-based experiment to study biomass burning in Indonesia. The experiment, the Pacific Atmospheric Chemistry Experiment (PACE-6), was a sequel to the aircraft experiment conducted in Indonesia at the height of the 1997 forest fires in Kalimantan.

Biomass burning and air quality

Jørgen Jensen

This time, CSIRO and BMG scientists made measurements from near Palangkaraya. Measurements included aerosol particles and solar radiation, using a five-band sun-photometer. An extensively instrumented research aircraft flew over central Kalimantan, monitoring trace gases such as sulfur dioxide, oxides of nitrogen and ozone. Also measured were aerosol particles, cloud condensation nuclei and giant nuclei, cloud and precipitation drops, and shortwave and longwave radiation.

Since the demise of El Niño at the end of 1997, there has been very extensive rainfall over central Kalimantan. Last year, there were only a few small fires in the rain-forest plains of central Kalimantan. However, in the hills to the north — where it is less swampy — there were numerous small-scale biomass fires.

The severe 1997 fire season and the more normal 1998 fire season provides us with the full spectrum of air quality: from very clean, through to catastrophic biomass-fire affected. Our suite of measurements gives us very useful data for evaluating the effects of the 1997 forest fires.

The experiment was supported by CSIRO, the Australian Government through the Australian Agency for International Development (AusAID), and by MRI in Japan.

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Aerosol over south-east Australia

What is the source of the springtime increase in tropospheric aerosol over Australia? This was a question that Dr Stuart Young hoped to answer during a field experiment in Mildura, in Victoria's north-west.

Dr Young joined eminent aerosol researchers Prof. James Rosen and Dr Norman Kjome from the University of Wyoming for the four-week experiment.

'We immediately found greatly enhanced concentrations of both aerosol and ozone in the supposedly-clean free troposphere,' says Dr Young. Over Mildura, the free troposphere stretches from about 2 km to 12 km above the ground.

The team probed the atmosphere with a CSIRO ground-based lidar (an instrument that fires a laser beam into the air and then analyses the reflected light) and with particle counters, backscatter sondes and ozone sondes carried as high as 30 km by large balloons.

Subsequent trajectory analyses suggest that the aerosol observed over Mildura came from Africa, taking about eight days to reach Australia. It was also possible that aerosol came from as far away as South America.

'One possible mechanism for what we saw is that thunderstorms carry aloft gases from tropical forest fires. The gases then react to form particles that circle the globe,' suggests Dr Young.

The experiment's most significant findings showed that at times the aerosol contributed significantly to total aerosol optical thickness, a quantity that affects the balance of radiation in the atmosphere. The aerosol layers also extended some hundreds to thousands of kilometres upwind.

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CSIRO, Bureau of Meteorology and British scientists have spent summer studying the 'self-cleansing' ability of the atmosphere. They were participating in a major international project called the Southern Ocean Atmospheric Photochemistry Experiment, based in north-western Tasmania.

Where does all the air pollution go?

Air contains naturally occurring chemicals called hydroxyl radicals that react with, and destroy, a range of pollutants and other compounds.

'If levels of hydroxyl radicals are changing, one consequence may be increasing concentrations of ozone gas in the lower atmosphere,' says Professor Stuart Penkett, from the University of East Anglia in the UK. Professor Penkett was a project leader for the experiment.

Ozone near the ground is both a greenhouse gas and an irritant that attacks the throat and lungs and irritates the eyes.

'A change in ozone and hydroxyl radical concentrations in the lower atmosphere would certainly affect stability of the world's climate,' says Professor Penkett.

'The Experiment is giving us a present-day baseline in the cleanest air present in the atmosphere against which we can check future changes. We will also use our results as a comparison for similar studies in the more polluted northern hemisphere,' says Professor Penkett.

Rob Gillett calibrates the CSIRO peroxide measurement system.

The Experiment involved measurements from the Cape Grim Baseline Air Pollution Station, from research aircraft and from the CSIRO research vessel, *Southern Surveyor*. Leeds University, Leicester University and the University of East Anglia joined CSIRO and Bureau of Meteorology scientists for the Experiment.

Rebecca Webb, from the University of Tasmania, adjusts the aerosol sampler flow rate on the roof of the Cape Grim station.

Ozone depletion: the latest news

Last year's springtime Antarctic ozone hole reached record levels, covering approximately 26 million square kilometres, which is approximately three times the area of Australia.

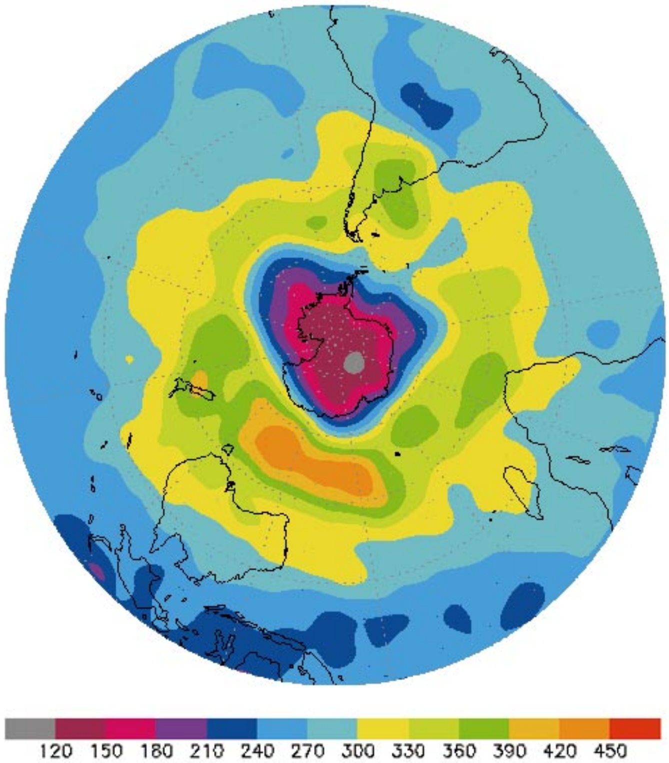
The middle of August heralded a steep decline in ozone. The hole reached a maximum on 21 September. Ozonesonde measurements revealed almost total destruction of ozone at heights between 14 and 22 kilometres.

Eminent US researcher, Dr Susan Solomon, from the National Oceanic and Atmospheric Administration, presented the latest information on stratospheric ozone depletion during her 1998 Priestley Lecture. The Priestley Lecture is named in honour of the founding Chief of CSIRO Atmospheric Research, Dr Bill Priestley.

'Unfortunately, it's going to be several decades before we see the end of the Antarctic ozone hole,' said Dr Solomon.

Dr Solomon discovered that chemical reactions destroy ozone on surfaces such as the ice crystals within high-altitude 'polar stratospheric clouds' as well as on other atmospheric particles high in the atmosphere.

Dr Susan Solomon, from NOAA, presenting the latest information on ozone depletion



TOVS Total Ozone Analysis. Climate Prediction Centre/NCEP/NWS/NOAA

1998 Antarctic ozone hole.

'We're clearly seeing a major impact on ozone depletion caused by the eruption in 1991 of Mt Pinatubo in the Philippines,' said Dr Solomon.

'Just like polar stratospheric clouds, volcanic particles make chlorine from CFCs more effective at ozone destruction.'

'Chemical reactions on the volcanic sulfate particles blasted into the stratosphere by the eruption accelerated ozone depletion due to chlorine over the southern hemisphere by about 3 per cent. It is only now that this extra depletion is disappearing.'

The Antarctic ozone hole and the year-round depletion of the Earth's protective ozone layer will continue until levels of ozone-destroying CFCs and halons drop to pre-1970s concentrations, around the middle of next century.

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Air quality for people living in Australia's major cities can be improved by more than 50 per cent in future by careful urban planning according to a recent CSIRO report.

According to the report, the best pattern for expansion in order to reduce exposure to air pollution is a city in which growth occurs along corridors radiating from the central business district, supported by improved public transport.

Reduce air pollution: redesign your city

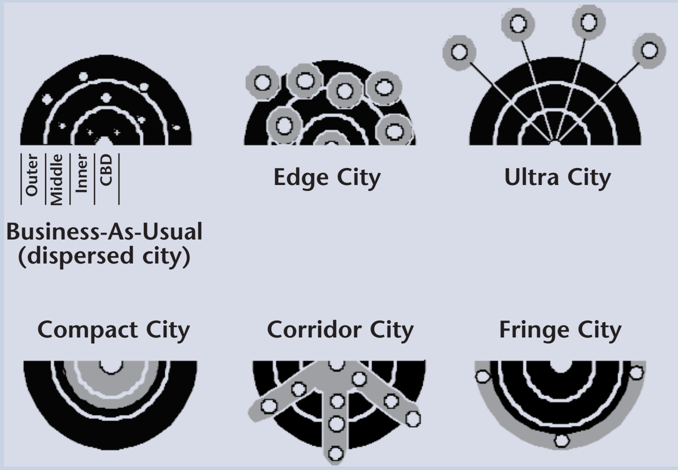
'Developing cities along corridors can lower people's exposure to photochemical smog by over 50 percent. In addition, our exposure to fine particles associated with haze and ill health would drop by about 15 per cent,' says Dr Peter Manins.

Dr Manins and Dr Peter Newton, from CSIRO Building, Construction and Engineering, have calculated how different city forms would influence people's exposure to air pollution in the year 2011 with an increase in population of 500,000, compared with a base year of 1991 for a city of 3 million people.

'When it comes to greenhouse gases, such as carbon dioxide, a shift to a compact city with increased inner suburban density would produce a reduction in emissions of about 40 per cent,' says Dr Manins.

The compact city is also far more efficient for fuel use, which is likely to be more than 40 per cent less than it would be under an extension of current city design.

'If we simply continue with current patterns of urban growth, we can expect that exposure to photochemical smog will worsen by more than 70 per cent and exposure to particle pollution will rise by more than 60 per cent,' Dr Newton warns.



The six different city forms considered in the CSIRO study

'Our main finding is that if we don't properly plan our cities, we will condemn population and industry to a less ideal living and working environment in future,' says Dr Newton.

CSIRO examined six alternative city forms to assess the impact of each on future air quality. The city forms included: business-as-usual, an extension of current development practices; an 'edge city' with growth at selected nodes; growth in regional centres within a hundred kilometres of the CBD that are linked by high speed trains; a compact city; a corridor city; and a 'fringe' city, with growth predominantly on the outskirts.

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Celebrating 50 years of atmospheric science

CSIRO Atmospheric Research recently published a book to celebrate 50 years of science.

The Division began operations in the late 1940s in a small garage and an ex-army hut in Highett, at the site occupied today by Building, Construction and Engineering. Shortly after, the Division moved to the wide, open spaces of Aspendale, a bayside suburb about 30 kilometres south-east of the Melbourne CBD.

In the early days, scientists established programs to learn more about Australia's weather, both to improve forecasts and to help farmers. Researchers in the 1950s studied sea breezes and other weather systems. They also built a wind tunnel to learn more about air flow near the ground and around obstacles.

During the following decades, Divisional scientists launched balloons to probe the atmosphere and the ozone layer. They measured how much solar energy penetrates the atmosphere. They organised world-famous experiments in Mount Gambier, Hay and Rutherglen to learn more about cold fronts, wind in the lower atmosphere, and environmental effects on plants.

In the 1970s, as concerns grew about global pollution, CSIRO and the Bureau of Meteorology built the Cape Grim Baseline Air Pollution Station in north-western Tasmania to monitor the composition of air. Today, this laboratory is the most advanced of its type in the southern hemisphere.

CSIRO Atmospheric Research in the 1950s and today.

Throughout the 1990s, Atmospheric Research scientists have probed the greenhouse effect, air pollution, ozone depletion and El Niño using analytical and remote sensing tools and computer-based models.

Winds of Change: Fifty years of achievements in the CSIRO Division of Atmospheric Research. Available from CSIRO Publishing, ph +61 3 9662 7500; http://www.publish.csiro.au.

Applying our research

Significant recent and ongoing projects

Malaysian haze study	AusAID
Australian national greenhouse gas inventory	Australian Greenhouse Office
Climate change and variability over Victoria – implications for water resources	Department of Conservation and Natural Resources, Victoria
Assessment of sea level rise under climate change	Gold Coast City Council
Air quality modelling systen for Hong Kong	Hong Kong Environmental Protection Department
Industrial plant emissions and the environment	MIM
Climate change under enhanced greenhouse conditions	Queensland Government
Impact of the Kyoto Protocol on Pacific Islands	South Pacific Regional Environment Programme
Seasonal forecasting and climate variability	Western Australian Government