Keeping watch on the world's air

In the last issue of *Ecos* we published an article about carbon dioxide levels in the atmosphere. It cast doubt on the now widely accepted view that the world's carbon dioxide levels are rising because of the fossil fuels burnt in industrialized countries. Instead, it suggested, concentrations of this gas in the atmosphere pass naturally through long cycles in which the levels rise and fall considerably.

The implication of this theory was that the natural cycles are so large that they will swamp any effects that Man can produce.

Like most other ideas that have been put forward about climatic trends, this one depends on indirect evidence. In this particular case the theory was derived from studies of the annual rings in Tasmanian trees.

Indirect evidence can often be interpreted in several ways, which explains why scientists frequently disagree. To find out whether recent carbon dioxide rises really are part of a natural trend or man-made, or whether for that matter carbon tetrachloride from the chemical industry and fluorocarbons released from aerosol cans really are accumulating and so may eat away the ozone layer, we need direct long-term measurements from places remote enough to be unaffected by local industrial contamination.

Such 'baseline' measurements have not (until very recently) been available. Carbon dioxide levels have been monitored longer than any other atmospheric feature, but accurate measurements of even this gas date only from 1955—not long enough to do more than indicate short-term trends.

International recognition of this lack came in 1972. That was the year of the United Nations Conference on the Human Environment in Stockholm. This conference set up 'Earth Watch', the United Nations Environment Program, to which the Australian government pledged 'full cooperation'. The 79th recommendation emanating from Stockholm proposed that a network of about 10 'baseline' stations should be set up around the world. These would 'monitor long-term global trends in atmospheric constituents and properties which may cause changes in meteorological properties, including climatic changes'. The same Stockholm recommendation also called for the establishment of a larger network of not less than 100 regional stations to monitor the local atmosphere—with the aim, in particular, of recording changes in the distribution and concentration of contaminants. Programs for the networks of both types of stations would be guided and coordinated by the World Meteorological Organization (WMO).

Mrs Helen Goodman of the Division of Atmospheric Physics changes filters in the high-volume dust sampler at Cape Grim.

Australia commits itself

In October 1972, shortly after the conference, Australia indicated to the United Nations General Assembly that it would be willing to consider establishing both baseline and regional stations. In June 1973 it formally notified the United Nations Environment Program (UNEP) that it would indeed set up the baseline station and regional stations. Early in 1976, Australia began making preliminary baseline measurements at Cape Grim at the north-western corner of Tasmania.

At present, only the United States has any permanent baseline stations that are fully operational. It has four—in Alaska, Hawaii, and American Samoa, and at the South Pole. Although the American program was already in motion before the Stockholm conference, its stations are run in close conjunction with UNEP and so may be regarded as a part of the international network.

Australia's present baseline monitoring arrangement at Cape Grim is temporary —with its instruments housed in an equipment trailer on indefinite loan from NASA. In a spot as windy as Cape Grim this has its disadvantages. For instance, to eliminate the effects of the van's shaking, the instruments measuring carbon dioxide levels are now mounted on a pillar that juts up through a hole in the floor. The pillar is anchored into a concrete slab set in the ground.

As well as vibration, temperature variations within the van, a lack of facilities for calibrating, checking, and repairing instruments, the rather primitive arrangements for recording and processing measurements, and other inconveniences make things difficult.

Even so, some accurate baseline measurements are being made on a routine basis, and it has been possible to develop techniques for making baseline measurements and to test them out.

The Australian government is considering proposals for a permanent baseline station. With the experience already gained at Cape Grim, it will be possible to quickly bring such a station into operation should the government approve it.

To be of value, the baseline measurements will have to be taken continuously for 50 years cr more, so a permanent station will need to be solid enough to remain in operation for a very long time.

Good location

Australia is well placed for making baseline measurements. It's one of the few land masses in the Southern Hemisphere, and it straddles two distinct air masses—the easterly trade wind belt, and the temperate westerly one. In addition, much of the man-made contamination of the world's atmosphere originates in the industrialized countries of the Northern Hemisphere. It's easier to detect atmospheric trends far away from the sources of contamination.

Baseline stations need to be in remote places. This is the American one at the South Pole.

Urban and background air compared for gas concentrations (parts per million)

	urban air	background air
carbon monoxide	5–50	0·1
nitrogen dioxide	0·02–0·2	0·001
sulphur dioxide	0·2–2	0·002
surface ozone	0·1	0·01

Gases in background air usually occur in much lower concentrations than in city air. Instruments used for monitoring city air pollution are of little use when making baseline measurements.

A preliminary study in 1972 by Dr Bill Priestley, who recently retired as Chairman of the CSIRO Environmental Physics Research Laboratories, and Dr Bill Gibbs, Director of Meteorology, suggested that we could most usefully concentrate on the westerly belt. South of the equator, the Americans were already building their Samoan station to monitor the easterly trade winds, and the South Pole observatory for the Antarctic air mass had already been monitoring some items for 15 years. The Americans had no stations planned for the westerlies.

Dr Priestley and Dr Gibbs concluded that a station monitoring the westerly wind belt would have to be in Tasmania, since this is the only part of Australia that consistently remains within the westerlies all year round.

Features to be monitored

What does a baseline station measure? The World Meteorological Organization expects the baseline network to monitor 'background levels of those pollutants which have a potential effect upon climate'. This is a pretty vague directive. In practice we still know so little about how the atmosphere operates that deciding which factors affect our climate is really little more than educated guesswork.

Baseline records need to do two things. They must:

- give continuous records of background levels of possibly undesirable substances that Man puts into the atmosphere
- yield knowledge about the world's atmospheric processes, so that the records can be interpreted

Our activities can possibly affect our climate in several ways. For example, we may be increasing atmospheric carbon dioxide by burning fossil fuels, thus causing the world to become warmer (the greenhouse effect). Adding fluorocarbons such as the two Freons or water vapour will also have the same effect. (Of course, adding fluorocarbons or the oxides of nitrogen to the atmosphere may also be reducing the ozone layer.) Conversely, we may be cooling the climate by adding huge quantities of tiny particles to the atmosphere—in particular from industrial chimneys.

The particles may be cooling the climate in two ways—by directly scattering incoming sunlight so that more is reflected into space, and by altering the earth's cloud cover. The direct scattering effect may well be relatively localized since it will be caused by the largest particles, which fall out of the atmosphere or are washed out by rain fairly quickly.

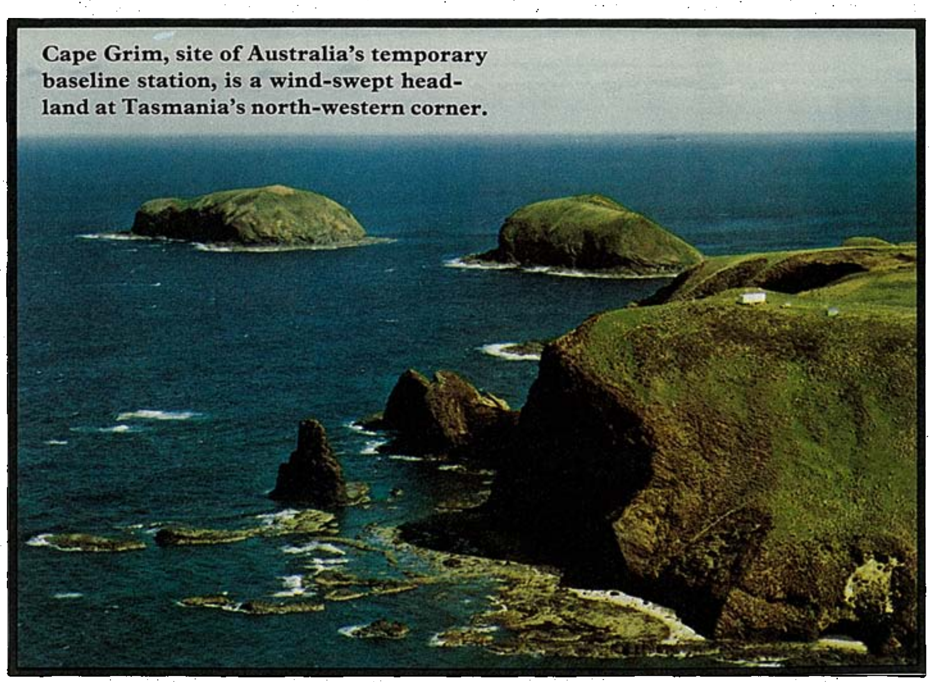
Probably more important are the effects on the cloud cover of the much more numerous very small water-absorbing particles. These are far too small to fall out of the atmosphere. Cloud droplets form on them, so their presence may alter both the light-reflecting properties of the cloud cover and the amount of rain it produces. Although these very small particles are washed out by rain, they are also continually generated by extraneous gases in the atmosphere such as sulphur dioxide (see *Ecos* 11).

No doubt there are other ways in which we are unwittingly affecting the atmosphere—the recent realization that spray-can propellants may be breaking down the ozone layer is a good example (see *Ecos* 6). So a baseline measurement program needs to be flexible enough to allow monitoring of additional items should this seem desirable.

In its 'Operations Manual', the World Meteorological Organization has laid down the minimum program that should be carried out at a baseline station as monitoring the following:

- carbon dioxide levels
- turbidity (opaqueness) of the atmosphere
- radiation reaching the ground
- chemical composition of rain
- meteorological measurements (wind speed and direction, rainfall, temperature, humidity, pressure)

In addition, the Organization states, it would be very desirable to measure the total ozone levels in the atmosphere.



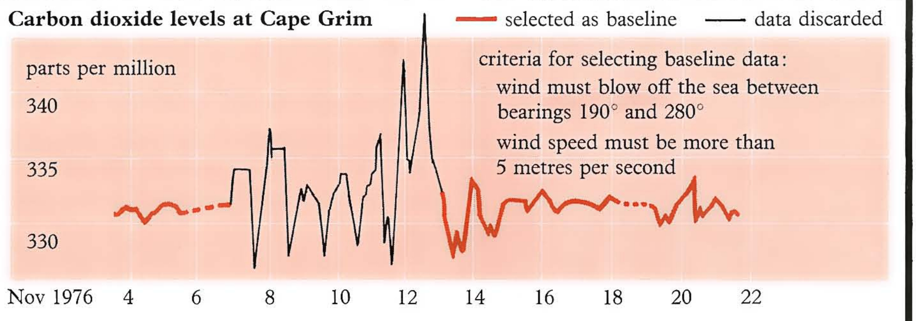
Cape Grim, site of Australia's temporary baseline station, is a wind-swept headland at Tasmania's north-western corner.

Cape Grim's program

Measurements currently being taken at Cape Grim closely parallel those being made at the American observatories. They include all five of the WMO's top-priority measurements. Total ozone in the atmosphere is not being monitored at Cape Grim, since the CSIRO Division of Atmospheric Physics has been measuring this item at Hobart for some years already. Doing so would be a part of the program of the permanent baseline station.

In addition, the Cape Grim station measures ozone levels at ground level, atmospheric concentrations of carbon tetrachloride (CCl_4) and the fluorocarbon Freon-11 (CCl_3F), and the numbers, composition, mass, and distribution of particulates in the atmosphere. By the time this article comes into print, instruments should also be recording atmospheric levels of the oxides of nitrogen. Monitoring sulphur dioxide has been mooted.

Taking baseline measurements is no easy task. The site must be very carefully chosen. The samples taken must as nearly as possible be representative of the whole air mass above the station. They must therefore be free from any local contamination—be it natural or man-made. Also, concentrations of some atmospheric constituents are very low. So the instruments must be very sensitive, accurate, and reliable to allow taking of routine measurements that may be compared with one another and with those taken elsewhere.



Plants giving off carbon dioxide by night and mopping it up by day caused the large daily variations in levels of this gas between November 8 and 13. Winds blew from off the land for this period.

To ensure complete cleanliness of the air sampled, the World Meteorological Organization has laid down in its 'Operations Manual' a number of extremely restrictive conditions for choosing a site. For example, it suggests that baseline stations should preferably be located on remote islands or on mountains above the treeline, or at least in areas away from centres of population, major highways, and air routes, where no local land use changes are expected within a radius of 100 km for at least 50 years.

Obviously meeting such conditions would be well-nigh impossible in many parts of the world. We don't have any mountains high enough, and anyway running such remote stations would nearly always be prohibitively costly—so expensive in fact that even the Americans have had to compromise when choosing their sites. Indeed, only two of their four observatory sites are remote—at the South Pole and at Barrow on the western tip of Alaska—and only the one at Mauna Loa, Hawaii, is high up on a mountain above the treeline at an altitude of 3400 metres. (The South Pole station is located at 2800 metres on the polar plateau. Mt Kosciusko, our highest peak, only reaches 2228 metres above sea level.)

Keeping measurements up to scratch

It's one thing to decide to make long-term measurements of selected baseline information; doing so is quite another. Sulphur dioxide and the oxides of nitrogen, for example, are gases that have caused concern recently, and their levels are constantly measured near cities in many parts of the world. But, compared with the air at baseline sites, levels of these gases in the air near cities are high.

Background levels in clean air are very low indeed. Consequently, little of the technology developed for monitoring city pollution is much good for making baseline measurements—it just isn't sensitive enough. So monitoring the minute changes taking place in clean air has involved developing new technology for the purpose, and even now there's a great deal of room for improvement. A good deal of the equipment at both the American and Australian baseline stations can still be regarded as experimental.

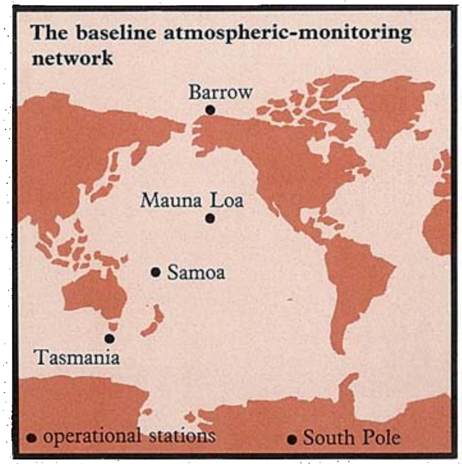
Even when you have equipment that is sensitive enough, and that can consistently measure to the accuracy required, it's difficult to know how to interpret the results—are minor variations in the records real or do they stem from the instruments? Even if they are real, do they reflect changes in the air mass, or merely some unexpected local source of contamination?

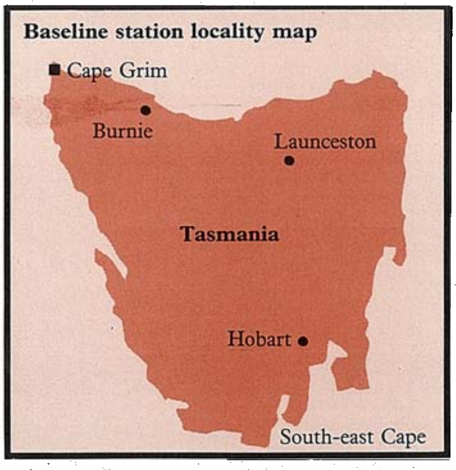
Being so sensitive, the instruments will detect any contamination from local sources, however minor. For instance, on the wrong wind, particles produced by the station staff when cooking their meals will greatly increase the local concentration, making particulate measurements useless. Exhausts of vehicles may have the same effect.

At Cape Grim, as at Samoa, even the local vegetation affects the results. Plants put out carbon dioxide by night and mop it up by day. When the wind blows from off the land the instruments of Cape Grim reveal regular variations in the carbon dioxide levels by day and night. Even when the wind blows off the ocean from the west or south-west, very slight variations still occur. These probably result from the photosynthesis and respiration of plankton in the surface waters of the sea. But we have no reason to doubt that the readings of about 330 p.p.m. obtained with the winds in this quarter are true baseline readings.

Another difficulty for the baseline station network arises when results are compared, to build up a world picture. In spite of their accuracy, different measuring techniques may still give slightly different results—even when they have been meticulously calibrated against one another. For this reason, frequent comparisons have to be made between instruments at all the stations in the network.

Baseline measurements must consistently remain so accurate that any lapse in standards makes the whole exercise useless. So the measurement program has to be done either properly or not at all.





Both the Mauna Loa station and the one on American Samoa are quite close to large towns, but an inversion layer that develops down at about the treeline protects Mauna Loa by night, and the Samoan station, located on a promontory jutting out into the Pacific, is swept by winds that rarely blow off the land.

Thus at both these stations baseline measurements can only be taken when the wind is blowing from an uncontaminated quarter. In practice, winds blowing from the right direction for about half the time allow very adequate records from a baseline station.

As with the American stations, Cape Grim represents a compromise site, and here too winds only blow from a suitable direction for about half the time.

Where to put the station?

The search for a site began in 1972 with the preliminary study by Dr Priestley and Dr Gibbs. During the years that followed, the hunt concentrated on southern Tasmania—following the logic that the further south you go into the westerly belt, the greater the number of days per year you have available for sampling this air mass.

To begin with, the CSIRO Divisions of Atmospheric Physics and Cloud Physics put in recording instruments at Adamson's Peak west of Dover, and at Hartz Mountain in the Hartz Mountain National Park. These sites seemed to offer remoteness at fairly high altitudes. However, they proved too inaccessible to make the project feasible. In addition, fires occur quite frequently in even the remotest parts of Tasmania, and local vegetation affects carbon dioxide levels. So a coastal site without land to windward obviously had advantages.

In 1974, CSIRO, the Bureau of Meteorology, and the then Department of Environment set up instruments (with the permission of the Tasmanian government) near Bare Hill at South East Cape. However, although this site proved most suitable for taking baseline measurements, other considerations have all but ruled it out.

Instruments were first placed on Cape Grim early in 1976—on a remote, treeless pocket handkerchief of land owned by the Commonwealth government. More than a year of accurate monitoring of several atmospheric features, as well as of the meteorological conditions, has revealed that this too is a very acceptable site.

As at South East Cape, suitable winds blow off the ocean from the west or south-west for about 50% of the time. Winds with a northerly component may have blown across the Australian mainland and so picked up some local contamination (see *Ecos* 11). This of course also applies for winds crossing Tasmania. At Cape Grim, south-easterly and easterly winds in particular show raised levels of particles. These emanate from Hobart, Launceston, and Burnie.

The effect of the distant mainland on particle levels may seem surprising. But sampling flights made in 1974 by the Division of Cloud Physics revealed that our mainland air, although it is very clean compared with that of other continents, contains some two to three times more microscopic particles than air over remote oceans, or that over Antarctica.

Virtues and faults

The very windiness of Cape Grim is an advantage for taking measurements, if not for the people working there. The winds help to make sure that the air at ground level is well mixed with that higher up. This means that the air samples probably really are representative of the whole westerly air mass.

Perhaps the main fault with the Cape Grim site is the large amount of salt in the air, which makes interpretation of chemical analyses of rain-water more difficult. In addition, on the rare still days after westerly gales, particles coming off rotting kelp on the shore beneath the station contaminate the samples. The latter problem doesn't arise when it's windy.

The preliminary baseline station at Cape Grim (known using the correct WMO terminology as BAPS—for Baseline Air Pollution Station) is run by the Commonwealth Department of Science, which now has two technicians on site. Much of the equipment has been developed by the CSIRO Divisions of Atmospheric Physics and Cloud Physics, using funds provided by the Department of Science and by the Department of Environment, Housing and Community Development. Currently a working group advises the manager of the baseline station program, and this working group consists of representatives of the Department of Environment, Housing and Community Development, the two CSIRO Divisions, the Bureau of Meteorology, the Australian Government Analytical Laboratories (AGAL), and the Tasmanian Department of the Environment.

Storing the results from the station will be the responsibility of the Department of Environment, Housing and Community Development in its planned data bank at the National Air Quality Data Centre at Canberra. These results will be available to Commonwealth and State environment and health departments, and to research institutions like the universities and CSIRO. The Department will also carry out Australia's international obligation of communicating specified information to UNEP.

More about the topic

'Geophysical Monitoring for Climatic Change Summary Report Numbers 1–4.' (National Oceanic and Atmospheric Administration: Boulder Colorado, 1972, 1973, 1974, 1975.)

'WMO Operations Manual for Sampling and Analysis Techniques for Chemical Constituents in Air and Precipitation.' (World Meteorological Organization: Geneva 1974.)

Measurement of atmospheric composition at the Australian baseline atmospheric monitoring station. G. I. Pearman. Proceedings of the Symposium on Analytical Techniques for the Determination of Air Pollutants. (Clean Air Society of Australia and New Zealand: Melbourne 1977.)