Next year's weather - the largest scientific experiment ever

Experiments are the stuff of science. And for meteorologists seeking to comprehend the fickle ways of the weather, their laboratory is no less than the entire atmospheric mantle of our globe.

That's a big laboratory. It makes it very difficult to find out why the atmosphere carries on with its antics in just the way it does.

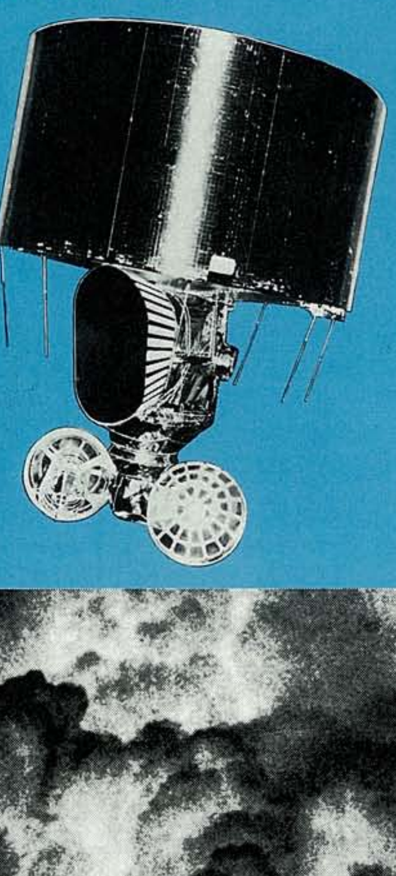
However, that doesn't deter the determined meteorologist. While we are apt to view the weather as obstinately unpredictable, he, of all scientists, has probably the most unbounded faith in the order of nature. His strictly scientific attitude is that every effect has a cause, and if we know a cause, then of course the effect can be predicted.

The atmosphere, and its weather, is therefore likened to a piece of clockwork—phantasmagorically complex, yes, but one whose inner workings are amenable to probing so that it's possible to find out what makes it tick.

For our man of the weather, a preferred mechanistic model is that of the atmospheric heat engine, a device charged by the energy of the sun and whose visible manifestations are the ceaseless goings-on of the weather. Forecasting is really a matter of working out what the engine is going to do next.

Laplace, that eighteenth century French philosopher, would have made a good meteorologist. He thought that if a superhuman intelligence knew the position of every particle and the forces acting on it, then the future could be determined. The only catch, of course, is that there are an awful lot of particles.

The Japanese meteorological satellite is one of five spaced around the equator to observe all the world's weather.



The meteorologist knows something about the behaviour of a number of these particles from reports of barometric pressure, wind speed and direction, air temperature, humidity, and so on, which come from many observing sites all over the world several times each day. Of course, the number of sites and the data they produce are limited, especially in the oceans of the Southern Hemisphere.

But if we could get all the necessary data . . . ?

Global Weather Experiment

Well, a monumental effort to obtain as complete a set of global data as technology and resources can provide will be conducted from this December to December 1979. Called the Global Weather Experiment, it will be the largest scientific experiment ever undertaken.

Next year's exercise will, alas, probably be the experiment to end all experiments.

Thousands of scientists from virtually every country will be putting to work the most sophisticated tools, such as earth satellites, instrumented aircraft, ships, balloons, free-floating ocean buoys, and gigantic high-speed computers. The earth's entire atmosphere and sea surface will be subjected to the most intensive study and surveillance. This ambitious project will operate continuously for the year and will include two separate 2-month periods of even more intense observations of the tropics and Southern Hemisphere.

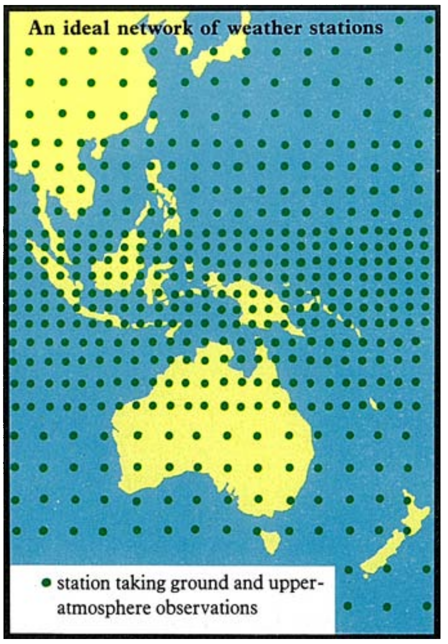
The direct cost of the whole operation is estimated to be as high as several hundreds of millions of dollars. Indirect unseen costs might well be about 10 times greater.

What an experiment! Will it work?

Yes, says Dr Brian Tucker, Chief of the CSIRO Division of Atmospheric Physics and chairman of the committee fostering the participation of Australian research groups in the analysis of the data gathered by the Experiment. He points to the past successes of the World Meteorological Organization (WMO), which is mounting the Experiment. One of WMO's major research activities is the Global Atmospheric Research Programme (GARP), a joint undertaking of WMO and the International Council of Scientific Unions, which has been operating steadily and fruitfully for over a decade. Scientists working on GARP believe they have developed mathematical models of the earth's atmosphere that mirror the behaviour of the real world pretty well. (The models are run on computers, and hence are usually called numerical models.) Such models are now routinely used in weather forecasting.

In Australia, development of these models is being carried out by the Australian Numerical Meteorology Research Centre, a body operated jointly by the Bureau of Meteorology and CSIRO.

So better data, Dr Tucker says, will allow scientists to refine their models and produce more accurate and longer-range forecasts. That's one thing the Experiment will provide. Second, an analysis of the mammoth data bank that will repose at the end of the experimental year should also bring out some of the factors determining climate (which can be simply defined as long-term weather).



Just a section of an ideal data-gathering network for the entire globe.

Upper-air soundings are just as vital as ground observations for running accurate numerical models.

The data will keep researchers busy for years. At least, so it is hoped, because next year's exercise will, alas, probably be the experiment to end all experiments. Initially, it was labelled the First GARP Global Experiment (FGGE), but the pure thought of organizing a second has led to a change in name. Now it's simply called the Global Weather Experiment.

Making a model

Better numerical models have become the holy grail of the weather forecaster. And it is the computer that has permitted this approach to bear fruit. The first mathematical model was devised about 60 years ago by L. F. Richardson, a British meteorologist. In principle, it allowed the weather to be predicted using mathematical equations based on well-known physical laws. However, it would have required 64 000 mathematicians working day and night with calculating machines to process data from 2000 weather stations across the globe.

Twenty-five years later, with the beginnings of the electronic computer, the technique became practicable. Today, powerful computers routinely produce tomorrow's weather map from today's data using numerical model programs. All that is required is for the forecaster to interpret the map in terms of weather, and in America even this task the computer is beginning to take over. One result is that the accuracy of forecasts there is steadily improving—and there are figures to prove it (for example, see the graph on page 7).

Without computers, WMO's operational arm, the World Weather Watch scheme (WWW), in which all countries pool and exchange their weather data, would never have been possible. In any 24-hour period, WWW collects and transmits millions of pieces of data. Daily weather observations are gathered from over 10 000 land stations (including nearly 1000 upper-air soundings), from some 7400 merchant ships, and from more than 1000 aircraft.

That's not a bad basis for operating a numerical model—it's enough data to keep even the world's biggest computer running flat out. Thanks to such powerful tools, forecasters can now produce fairly reliable forecasts for up to 3 days ahead in the Northern Hemisphere and, because of limited data, for half that time ahead in the Southern Hemisphere.

Information, incredible lots of it, is the key to unlocking the secrets of the weather.

The reason for the poorer performance is that 'holes' in the data start to spread out over the world, like a hole in stretched rubber, when the model is run. Similarly, errors in initial observations spread out and double every 2–3 days. Consequently modellers find it impossible to predict beyond a few days using current models and WWW observations. Models are still relatively crude in that they take little or no account of the effects of cloud or of the mutual interaction of sea and air.

If better data were available, researchers could refine their models. They could distinguish between those errors in the forecast due to inadequacies of their model and those caused by lack of good observations. An ideal set of data would be provided by observing stations spaced 500 km apart all over the globe (250 km apart in the tropics, where the greater quantity of sunshine received stirs the atmosphere more strongly). They would collect observations on pressure, temperature, humidity and wind at heights up to 30 km.

The ideal is unattainable, however, both for financial reasons and because we presently have no computer powerful enough to digest all the data. So the Global Weather Experiment is a compromise—between what is scientifically desirable, technologically feasible, and, of course, economically possible.

Bird's-eye view

The period that spawned the electronic computer also gave rise to another high-technology item, the Man-made satellite. Without it, we could say that WMO's ambitious Experiment would never have got off the ground. Satellites make truly global weather observations attainable.

For the Global Weather Experiment, five geostationary satellites spaced equally around the equator will continuously monitor all the world's equatorial and sub-tropical belts. Four of these are already in place, one of them being the Japanese satellite launched in July 1977. Its field of view takes in Australia, so it is appropriate that Australia has contributed to the cost of a ground station to monitor its operation.

A series of polar-orbiting satellites will also be brought into play to sense the temperatures of the earth's surface and of the

'Holes' in the data start to spread out over the world, like a hole in stretched rubber.

atmosphere at various heights. They will provide information on cloud coverage as well.

Additionally, two special research satellites will be at work. They will yield data on the earth's heat radiation, making it possible to estimate sea and air temperatures, moisture content of the atmosphere, and amount of sea ice. One of them will supply data on ozone levels and the other on wind speed and direction at the ocean surface.

The satellites will also perform the essential task of relaying data from ships, planes, buoys, and balloons to receiving stations around the world.

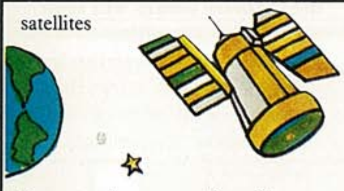
The responsibility for arranging Australian participation in the data-gathering aspects of the Global Weather Experiment rests primarily with the Bureau of Meteorology. Apart from maintaining the number of conventional meteorological observations at the highest possible level, the Bureau will also undertake to provide Australia's major contribution to the Experiment—the building, testing, and development of 50 drifting buoys in the southern oceans. As the diagram shows, the greatest lack of weather data occurs in the Southern Hemisphere. This is because of the vast ocean areas little plied by merchant vessels.

To try to make up for this lack, 300 instrumented buoys will be dropped into southern waters and left to drift. A drogue parachute connected to the bottom of each one will ensure that it drifts according to ocean currents, not surface winds. The battery-powered buoys will sense atmospheric pressure and the temperature of the sea surface and transmit these data to orbiting satellites. The location of each buoy is worked out from the apparent frequency of its transmission as received by the satellite.

The basic design of the buoy's hull follows that devised by CSIRO Division of Fisheries and Oceanography researchers, who have been using these satellite-tracked devices to investigate ocean currents around Australia. However, the Bureau has developed its own sensors and circuitry for the buoy's electronics package. Early in 1976, the Bureau built and launched five prototypes for testing. One of them transmitted data for more than 2 years.

Some of the special observing systems

satellites



five geostationary satellites will observe clouds and winds; they will also relay signals from balloons, buoys, and so on, to ground stations; a number of other satellites will observe temperatures, humidities, ozone levels, and surface winds

balloons

three hundred instrumented balloons will drift around the tropics at a height of 14 km; information on air temperature and pressure will be relayed back via satellite

dropsondes

six or more special planes will observe the monsoons from an altitude of 9–12 km; they will also release instrumented packages known as 'dropsondes'

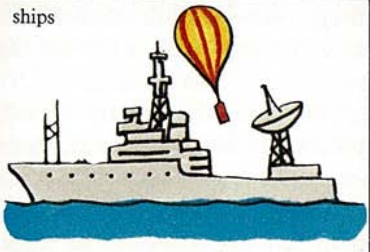
drifting buoys

three hundred instrumented buoys will drift in the southern oceans; data on atmospheric pressure and sea surface temperature will be relayed back by orbiting satellites

aircraft

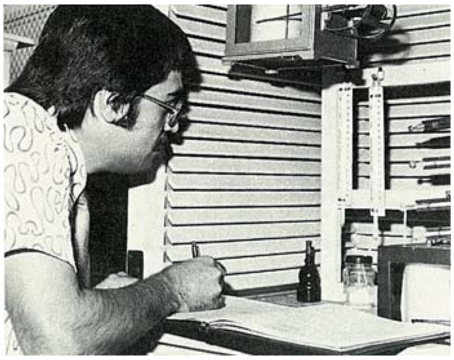
during their scheduled flights, 80 commercial aircraft will record data about winds, air pressures, and air temperatures on a cassette recorder; some other aircraft will send back their data via satellite

ships



forty or more ships will observe the monsoons; they will release instrumented balloons (to be tracked by radar)

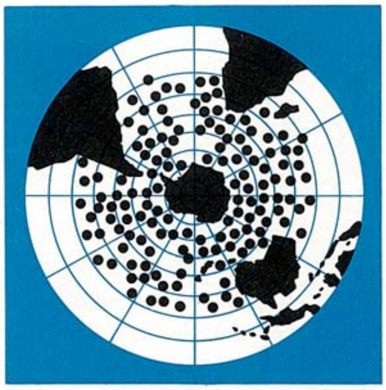
The Navy's survey ship HMAS Diamantina. **She will take part in observations of tropical monsoons.**



Meteorological observations—the starting point for numerical models of the atmosphere.

What the Japanese satellite sees from 36 000 km above the earth.

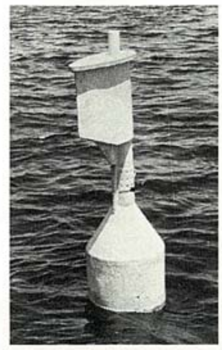
Drifting buoys in the Southern Hemisphere



Who supplies the buoys

Australia	50
Canada	80
Norway	50
United States	50
France	40
New Zealand	10

one of the buoys afloat



a buoy is helped into the water, where it will drift freely and monitor air temperature and pressure

Three hundred buoys drifting in the southern oceans will send back data via satellite. Australia's main contribution to the Experiment is the building and deployment of 50 of them by the Bureau of Meteorology.

Another idea being entertained is the building of some specially strengthened buoys to be lodged in the Antarctic pack ice.

A similar concept to the buoy scheme is a drfting balloon program. The United States has committed itself to putting 300 balloons aloft in the tropical belt to keep watch on upper-air behaviour there. They float along about 14 km up, and again data will be relayed back to ground stations via orbiting satellites.

In a complementary project, data on winds in the upper atmosphere will be obtained from 80 commercial aircraft during the course of their scheduled flights. Each aircraft will contain a cassette recorder that plugs into its inertial navigational system. By comparing the plane's ground speed with its air speed, the strength of upper-air winds can be recorded. Data on barometric pressure and air temperature are also collected. Most of the recorders will be on aircraft belonging to SAS, Thai International, KLM, and Swissair.

A more sophisticated arrangement, in which the data are not recorded on tape but sent back from the aircraft via overhead satellites, will also operate. It is planned for five Qantas jets to use this scheme; about 15 other carriers will also be provided with this monitoring equipment.

The active tropics

As if all this were not enough, there will be two periods during the Global Weather Experiment, each spanning 2 months, during which observations will be particularly intense. The extra activity will take place in the tropics, where presently available data are relatively sparse, like in the Southern Hemisphere. Yet the tropics are where the atmosphere is at its most energetic.

During the tropical monsoon periods (January-February and May-June), when the atmosphere becomes very active, an armada of ships and a number of specially equipped aircraft will arrive on the scene. Vessels will include the Australian Navy's *HMAS Diamantina* and CSIRO's research vessel, *Sprightly*.

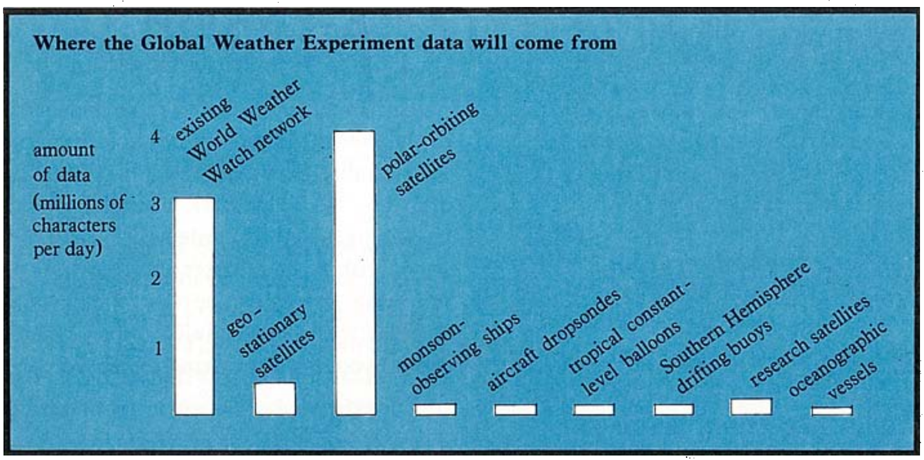
Balloons will be released from some 40–50 ships. Instruments carried by the balloons will transmit signals telling of the temperature, pressure, and humidity encountered during the ascent to their bursting point at an altitude of about 30 km. On the way up the balloons will be tracked by radar so as to discover the strength and direction of high-level winds.

For their part, the six or so planes involved will each day make observations along specially chosen tracks at an altitude of 9–12 km. For extras, they will release instrumented packages known as 'dropsondes'. These descend under a parachute and make readings of pressure, temperature, and humidity, which are transmitted back to the aircraft. In addition, they send back information on their position, derived from the Omega navigation system.

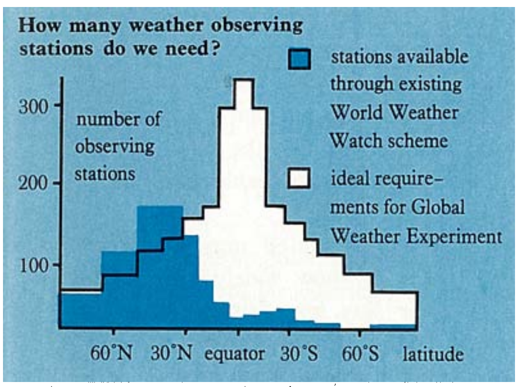
It is hoped that these dropsondes will plug the gap in our knowledge of what goes on during a monsoon. The gap is accentuated because of the small number of permanent observing stations in the tropics, and also because it's very difficult to persuade a balloon to go up through torrential rain.

Understanding the behaviour of monsoons is important not just for equatorial countries, but for Australia as well. Although the monsoon rains do not penetrate very far inland, they can influence our weather greatly, producing periods of flood or drought.

For instance, 1974 was one of the wettest years the Asian tropics had known. It was also a period of record rainfall for inland



The earth's entire atmosphere and sea surface will be subject to the most intensive study and surveillance.

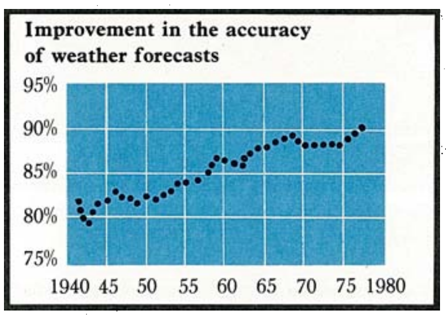


The existing World Weather Watch network already provides most of the Northern Hemisphere data needed for the Global Weather Experiment. However, data are lacking in the tropics and the Southern Hemisphere, and these are the areas where special observing schemes will be implemented during the Experiment.

Australia—Lake Eyre is still half full as a result. The 1974 monsoonal trough stretched as far south as Alice Springs, yet in 1972, a particularly dry year, the trough didn't even reach Darwin.

These 'anomalies' have attracted the interest of Dr Peter Webster of the CSIRO Division of Atmospheric Physics. He believes that the information gathered during the Global Weather Experiment will help him greatly in devising a satisfactory model for the Asian monsoons.

It is known that the winter monsoons are 'driven' by the most intense heat engine on the entire globe—the interaction of the hot equatorial region around the South China Sea with the cold Asian land mass surrounding Siberia. The massive air circulation set up by this heat gradient brings life-



The graph shows the percentage of correct rainfall and temperature forecasts at Chicago, U.S.A.

giving rains, but also gives rise to a number of effects whose precise nature is not known. Still a complete mystery, for instance, are the intermittent cold surges—outpourings of cold air from Siberia—which sometimes reach northern Australia.

Dr Webster is hoping the array of planes and ships will be able to 'catch' one of these cold surges in an observational net. With all the other data to hand, then, no longer will the winter monsoon remain the least observed and least understood weather pattern on the meteorologist's map.

Processing the data

We can see that information, incredible lots of it, is the key to unlocking the secrets of the weather. But what happens to the mass of data collected?

First, WWW's World Meteorological Centres—in Washington, Moscow, and Melbourne—will find a large increase in the amount of information coming to them. And they will get a lot of it almost as soon as it is generated. This will allow them to improve the quality of both their routine operations and their research.

Of greater significance, a consolidated set of all the data produced by the Experiment will accumulate at World Data Centres in Russia and the United States. At the end of the experimental year, the most intensive research will then begin. Using copies of the data tapes, research bodies will begin analysing the information.

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The Australian Numerical Meteorology Research Centre (ANMRC) in Melbourne, for instance, has three research programs lined up. The first is to evaluate how much better Australian weather forecasts become when a greater mass of data is available. Remember that the Southern Hemisphere has most to gain, since the Northern Hemisphere already has sufficient data for operating current numerical models. The Centre will concentrate on outstanding Australian weather happenings—storms, for example—which occurred during the two special intensive observing periods (when most data flowed in).

A second research program will look at the value of each avenue of procuring data. For example, are high-level balloon measurements more important in delivering the correct forecast than satellite observations? Which combination of data types is the cheapest one for reaching a correct forecast?

The third program of ANMRC's research will see how far into the future weather forecasts can be pushed in the Southern Hemisphere. Do we need a Global Weather Experiment every year to enable 3-day forcasts (common in the Northern Hemisphere) to be made for Australia?

With all this activity going on, we can only advise that all budding meteorologists and interested lay persons should not miss next year's weather—the greatest show on earth. People will be talking about it for years.

More about the topic

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