Outlook

If the sun no longer shone...

Mr Barrie Hunt.

What would happen to the earth's atmosphere if the sun stopped shining? That's hardly the most pressing question facing the world; the sun has thousands of millions of active years ahead of it.

But for scientists trying to find out why the atmosphere behaves as it does, it's a very interesting question. If they could watch what happened when the sun went cold, they would learn much about the links between the energy input from the sun and the processes that produce climate and weather around the world.

They can't make these observations of course, but at the Australian Numerical Meteorology Research Centre in Melbourne one scientist, Mr Barrie Hunt, has done the next best thing. Recently he simulated the demise of the sun in a mathematical model of the atmosphere, and came up with some very interesting findings.

For example, 50 days after the sun went out, the atmosphere was behaving in many ways as it did before, although much less vigorously. This result challenges the previously accepted view that it would virtually grind to a halt within 10 days.

Atmospheric modelling is a new branch of science; because of the vast amounts of data involved it would be impossible without high-speed computers. The job of some models is to forecast weather patterns up to a few days ahead. Scientists at the Research Centre work with that type as well as with 'general circulation' models of the type Mr Hunt used in his sun-stopping experiment. These are proving to be very handy research tools.

The energy that sets the atmosphere moving comes from the sun, so the amount of solar radiation reaching the earth must be the basic input to any model. Some of that energy is reflected back into space; the amount available to

According to Mr Hunt's model, the earth's atmospheric circulation would take more than 9 months to stop, if the sun no longer shone.

power the atmosphere — and the ocean currents — depends on many things, including the cloud cover and concentrations of carbon dioxide, ozone, and water vapour, which absorb heat. Models have to take account of all these things.

Earth-girdling winds

The equations that make up a model describe mathematically the processes that produce the major air movements in the atmosphere — the earth-girdling winds parallel to the equator and the north–south movements that convey heat from the tropics to the poles. The computer output shows how winds, temperature, and so on vary from place to place and change with time in the model atmosphere.

If the output closely matches measurements in the real atmosphere, the model is a good one. And if the model is good, the effects on its performance of changes to its input should resemble what would happen to the real atmosphere if those changes actually occurred.

He 'turned off' the sun and ran the model for 50 simulated days, watching what happened.

Mr Hunt used a model put together by researchers in America for his experiment with the sun. It is simpler than some general circulation models, dealing with only half the earth — from the equator to either pole — and not taking account of mountains or the pattern of land and sea. But it has proved itself a good model.

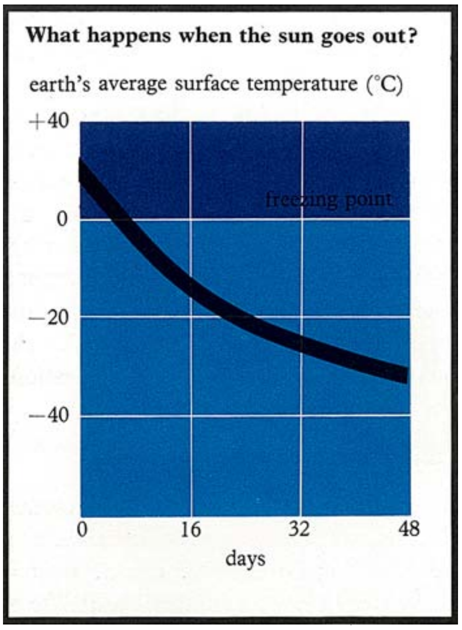
Mr Hunt first ran the model until it settled down into a fair representation of the real atmosphere's motion. Then he 'turned off' the sun and ran it for a further 50 simulated days, watching what happened.

One unexpected result was that north–south air movement slowed much more rapidly than the east–west circulation. Mr Hunt says this indicates that scientists are more likely to find explanations for changes in the earth's climate in north–south activity than in the much more stable east–west flow.

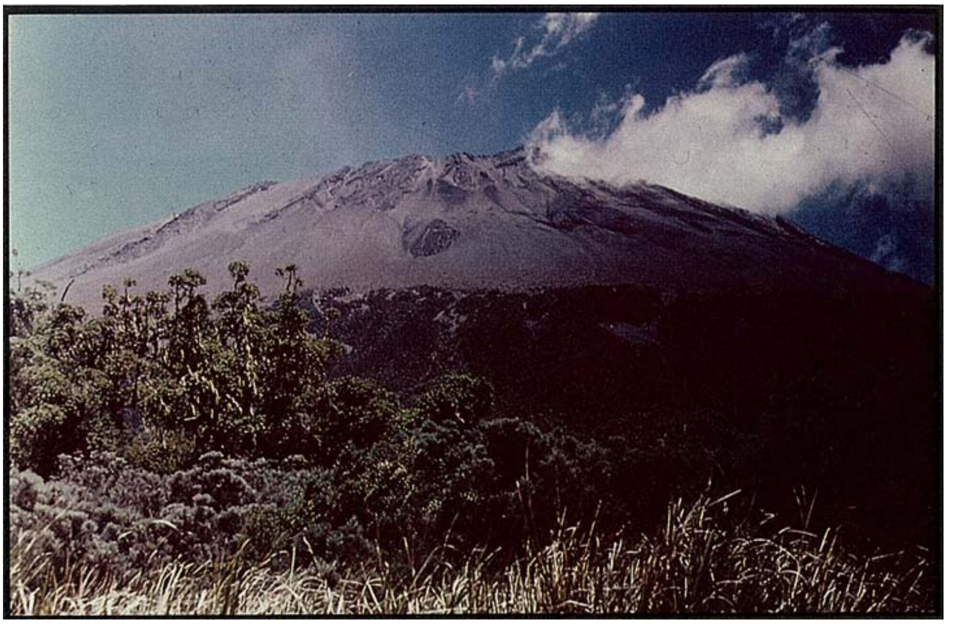
Very stable

One of the fears about Man's pollution of the atmosphere has been that it may destroy a delicate natural balance maintaining the atmosphere's main circulation patterns. The results of the experiment make this now seem less likely; the surprising persistence of these patterns after the sun's demise suggests that they are very stable. This does not mean pollution won't cause any climate changes — rather that it is unlikely to produce a basic circulation shift that would change climates everywhere.

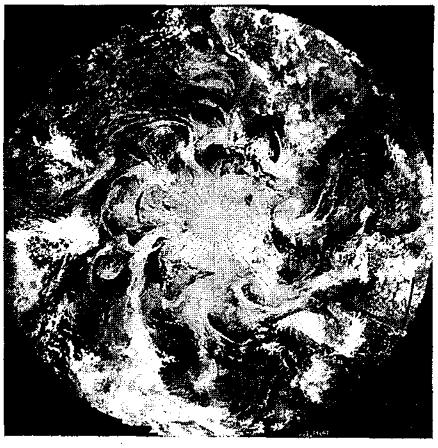
Incidentally, the model's temperature output shows that the earth would very soon become uninhabitable if the sun went out, despite the persistence of atmospheric activity. The average tem-



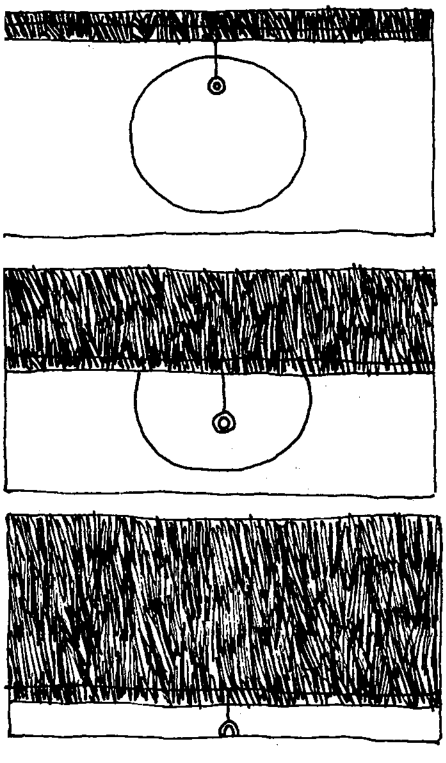
The rapid drop in the earth's surface temperature simulated by the model is for the latitude of Sydney.



Volcanic dust can reduce the solar radiation reaching earth. The model suggests it would take many simultaneous eruptions to trigger an ice age.



Cloud patterns over the earth viewed from the South Pole.



perature at the equator fell to freezing point within 12 days of the onset of darkness and to about −60°C within 48 days.

As well as throwing light on the workings of the atmosphere by showing the impact of drastic events that won't happen (at least for thousands of millions of years), the models can indicate the effects of lesser disturbances that may happen. But the smaller the disturbance being looked at, the better the model must be if it is to produce good results.

For example, overseas modellers obtained answers ranging from 0·3°C to 3°C when they tried to find out what average temperature increase could be expected at the earth's surface if the atmosphere's carbon dioxide content doubled. Models good enough to give a definite answer do not exist yet — all we can be sure of is that the temperature would rise, and probably by not more than 3°.

Mr Hunt recently carried out an experiment of this type. One theory explaining past ice ages is that debris tossed up by volcanoes cooled the earth by blocking solar radiation. Wanting to look at this cooling effect, he simulated the eruption of Krakatoa, which hurled something like 27 million tonnes into the stratosphere from the Straits of Sunda, Indonesia, in 1883.

The model showed the expected cooling in the tropics, where a temperature fall of about 0·5°C occurred. Further from the equator, cooling caused by the debris was harder to isolate from normal temperature fluctuations, but the fall averaged about 0·3°C over the whole Southern Hemisphere. One estimate of the average fall in temperature needed to bring on another ice age is 6°C, so it seems that much more than an eruption the size of Krakatoa's would be required. The model showed the volcanic debris diffusing from the tropics towards the poles during the 150 simulated days of the experiment.

One of the big problems modellers face is what to do about clouds.

A global model

Mr Hunt and colleagues at the Centre have just finished putting together a new model, which they hope will give more precise answers to the questions they ask. This one takes in both hemispheres, and provides for the different interactions that the atmosphere has with land and sea; for example, much more evaporation occurs from the sea. The model also takes account of mountains.

One of the big problems modellers face is what to do about clouds. The amount of solar radiation reaching the ground has a lot to do with the cloud cover, and probably nothing else in the sky is as variable and, so far, unpredictable as the area and thickness of cloud.

Some scientists have tried to use models to forecast cloud cover, basing their predictions on things that can be successfully forecast such as temperatures, pressures, and amounts of water

How volcanic dust dispersed

At a height of 20·5 km, dust spread over the whole Southern Hemisphere within 150 days of the simulated volcanic eruption of Krakatoa.

vapour in the air. But none of the attempts has been entirely successful. So what many modellers do is feed in average cloud cover figures for different latitudes, based on observations.

In an attempt to find out how important accurate cloud data are, Mr Hunt ran one of the models with all provision for cloud cover removed. Many changes appeared, but not in the basic circulation patterns and temperature distribution.

Mr Hunt thinks it's reasonable to conclude that no severe distortions in a model's picture of the real atmosphere result from the use of cloud averages. But it would certainly be desirable if models could generate and respond to their own simulated clouds. He is planning experiments in which cloud cover will be made to vary with the presure distribution; where there is a big depression, for example, a lot of cloud will be assumed. This should give a picture that is closer to reality.

He is also planning experiments to look more closely at the roles carbon dioxide, ozone, and water vapour play in distributing the energy that powers air movements. Carbon dioxide concentrations remain fairly constant throughout the atmosphere, but concentrations of the others fluctuate widely. The processes that cause the fluctuations have to be identified, and so do the effects of the changing concentrations.

Solar outbursts

It seems that bursts of activity on the sun can cause temporary reductions in ozone concentrations in parts of the atmosphere. These must change heating patterns, possibly sufficiently to affect the weather in some places.

Mr Hunt intends soon to look at what happens in a model atmosphere when such reductions in ozone concentrations occur. If significant weather changes result, this will create additional problems for forecasters, because solar outbursts can't be predicted.

One thing the models can do is show up links between abnormal weather conditions over an area and occurrences such as changes in ocean surface temperatures. Some rather sparse evidence exists associating droughts and floods in both Australia and North America with rises and falls in ocean temperatures.

In a series of experiments planned for the new global model, ocean temperatures will be systematically raised and lowered around Australia to see what happens to the weather systems. If clear links show up, this may prove helpful to forecasters, because satellites will soon be providing a lot of sea-surface temperature data.

Mr Hunt doubts that general circulation models will ever be able to provide definitive long-term climate forecasts. However, their role in predicting the consequences of things such as the ever-growing output of heat and carbon dioxide from fossil fuel combustion must become increasingly important. As the models improve, the range of questions they can answer will expand.

How it works

The development of better models depends on a growing understanding of the way the atmosphere works, so it is handy that the models also contribute to this understanding.

For example, meteorologists would love to know precisely what effects the earth's rotation has on the atmosphere. One way to find out at least part of the answer is to simulate a speeding up, and a slowing down, of the rotation and see what happens.

Mr Hunt has done this, by a factor of five in both cases. Interestingly, wind speeds increased greatly when the world slowed down and fell when it was speeding. Some other fairly dramatic changes in circulation patterns also occurred — interpretation of these is now beginning.

More about the topic

On the death of the atmosphere. B. G. Hunt. *Journal of Geophysical Research*, 1976, **81** (in press).

Experiments with a stratospheric general circulation model. I. Radiative and dynamic aspects. S. Manabe and B. G. Hunt. II. Large-scale diffusion of tracers in the stratosphere. B. G. Hunt and S. Manabe. IV. Inclusion of the hydrologic cycle. B. G. Hunt, *Monthly Weather Review*, 1968, **96**, 477–502; 503–39; 1976, **104** (in press).

Preliminary results from an upper atmosphere general circulation model. B. G. Hunt. *Proceedings of International Conference on the Structure, Composition, and General Circulation of the Upper and Lower Atmospheres and Possible Anthropogenic Perturbations, Melbourne*, 1974, 2.

Focus on Southern Hemisphere problems in dynamical meteorology. G. B. Tucker. *WMO Bulletin*, 1971, **20**, 232–7.

Numerical models of the earth's atmosphere. G. B. Tucker. *The Australian Physicist*, 1969, **6**, 179–82.