Jupiter's red spot, seen here behind Io, the satellite on the right, may be an example of blocking.

Blocking — when the weather stands still

When the TV weatherman points to a 'persistent blocking high' and talks of its continuing effect in preventing any change in the weather, he's talking about something that nobody understands very well. Controversy still surrounds scientific theories of blocking.

Scientists at the CSIRO Division of Atmospheric Research and the Bureau of Meteorology are engaged in studies aimed at providing a clearer insight into these enigmatic meteorological phenomena. They want to find out what causes blocks to come and go.

Intriguingly, recent computer simulations suggest that the processes causing blocking may be similar to those giving rise to Jupiter's giant red spot — an eye of stability amid that planet's turbulent atmosphere, which has been in place at least since Galileo saw it through his telescope some 350 years ago. Apparently, random eddies in a turbulent fluid, under the influence of steady rotation, heating, and topography, have the ability to spontaneously form stable structures. This happens when two eddies drift close, and then stick together.

The best evidence we have that we are getting close to understanding how and why blocking occurs comes from computer models of our atmosphere. Scientists in CSIRO and the Bureau have produced in these the characteristic blocking pattern that affects Australia's weather — a 'high' and 'low' pair over the Tasman Sea.

What is 'blocking'?

Blocking occurs when some feature of the normal eastward-moving weather pattern stalls. It may stay put for a few days, or for weeks. During this time the movement of 'highs' and 'lows' is deflected around the stalled feature as if it were a stone in a stream. The stationary feature usually consists of a cyclone–anticyclone (low–high) pair. The pair is usually oriented north–south, with the low nearer the Equator.

The consequences of blocking vary from drought to extensive heavy rain, depending on the location. Temperatures can also be extreme. In 1982 a series of blocking episodes in the Tasman Sea began at the end of May and blocks were continually re-established there for the remainder of the winter, causing (or at least being associated with) severe drought. More usually, though, blocking episodes persist for about a week.

The atmosphere may just 'tumble into' the process that causes blocking.

Forecasting the appearance, duration, and break-up of blocks presents a major problem for meteorologists. No single dominant cause of the phenomenon has yet been identified. Over the years, many theoretical mechanisms have been proposed to explain it.

The Australian branch of the Royal Meteorological Society held a conference on blocking in 1982 in response to growing interest in the subject. Blocking has been much better documented and analysed in the Northern Hemisphere than south of the Equator. Possibly this is because blocking episodes are less intense, on average, and less long-lasting in the Southern Hemisphere.

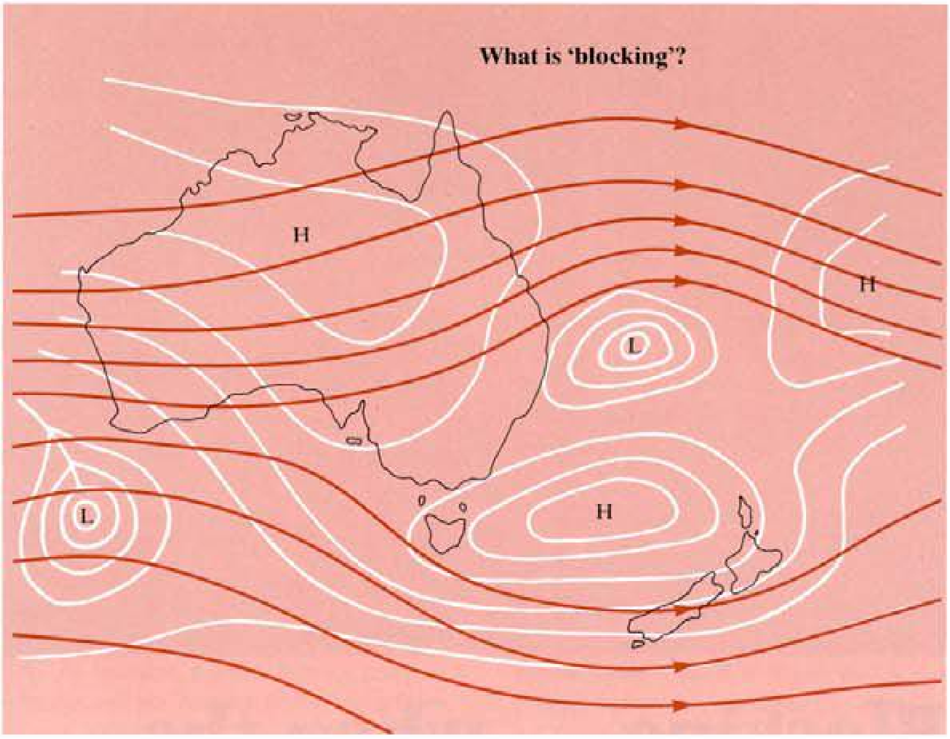
Blocks normally develop over the ocean. In the Northern Hemisphere the favoured locations are the north-eastern Atlantic and the north-eastern Pacific. In the Southern Hemisphere, three regions predominate: the Tasman Sea, south-western Atlantic, and south-western Indian ocean. The most common latitude for a blocking high is about 45 degrees.

Blocks usually don't move more than 20 degrees of longitude over a week, and more than 30 degrees over the duration of the episode. It is not necessary for the same high-pressure cell to persist throughout. An intense slow-moving high can fade, and then gain new life through interaction with some other feature such as a cold front. Or blocking can persist in the form of a largely stationary ridge, which is sustained by normal easterly-moving anticyclones. As they blend with the ridge these intensify; then they weaken as they pass on, leaving the ridge intact and stronger than before (although possibly displaced a little).

Sometimes blocks appear simultaneously at more than one location in our Hemisphere: double, or even triple, blocks are not uncommon.

Although blocking was first noted in 1904, the first attempted explanation did not arise until half a century later. It was suggested that blocking was some sort of 'hydraulic jump' in response to a perturbation in the atmosphere's circulation, caused by, for example, a range of mountains or a

An example of blocking, with the characteristic 'high' and 'low' pair stationary over the Tasman (surface pressure pattern in black). The upper troposphere pattern (colour) shows an air stream flowing around the block.



land–sea temperature difference. However, this notion did not hold up under examination.

Waves of instability

More recent studies suggest that, as well as 'steady-state' factors underlying the atmosphere's motion, 'dynamic instabilities' have to be examined in the search for an explanation of blocking. That is, as well as considering the steady flow from one point to another in the atmosphere, we need to take into account waves and ripples that might have significant effects a long way from where they begin.

Various types of waves propagate through the atmosphere, and scientists have developed a number of theories as to how such waves cause blocking. Dr Peter Baines of the Division of Atmospheric Research has reviewed the various theories; he favours a mechanism that Dr Jorgen Frederiksen (also at the Division) suggested in 1982. Recently, Dr Frederiksen was awarded the David Rivett medal, partly for his work on blocking.

The theory relies on the growth of instabilities in atmospheric flows. It supposes that small random fluctuations are initially present, and that the wave type with the fastest rate of growth emerges and becomes dominant.

This theory provides an explanation for the fact that blocking occurs where it does and usually involves a cyclone–anticyclone pair. Currently work is proceeding to identify the processes that create the flow that goes unstable. Topography or some temperature anomaly could be involved, but it is also possible that the atmosphere may just 'tumble into' the process that causes a blocking episode, because of a lurking instability.

Dr Frederiksen has since developed the theory more fully and incorporated it into a mathematical model that seems to reflect the real-life situation quite well. For example, the model gives rise to high–low blocking pairs (dipoles) when a parameter in it is set to values representative of less unstable atmospheric flow. This is consistent with observations by meteorologists that blocking tends to occur under conditions when the flow is less unstable than normal.

Indeed, if Dr Frederiksen increases the stability parameter still further, a whole family of stable multi-pole structures emerges. When he gives it smaller values, fast-moving monopole structures emerge — the birth of low-pressure cells (another mystery explained!).

A 'modon'?

For his part, Dr Baines has gone on to look at mechanisms that may help to maintain the blocking once it has been set up. His explanation involves a solitary 'Rossby' wave in the form of a 'modon' — a localized non-linear disturbance. In effect, according to this theory, the 'high' and 'low' of a blocking pair mesh with each other like gear teeth as they rotate in opposite directions.

'Highs' and 'lows' are deflected around the block as if it were a stone in a stream.

The concept was developed by theoretical oceanographers, but Dr Baines found the similarity to what occurs during blocking in the atmosphere so striking that he determined to look into it further.

He notes that blocking is a distinctly smaller-scale phenomenon in the Australian region than in the Northern Hemisphere, spanning only about 40 degrees of longitude. To him this suggests that blocking is a local event: it seems improbable that the waves involved would propagate right around the Hemisphere with sufficient strength to cause significant effects. (Of course, global effects may be important in 'setting the stage'.)

Dr Baines has found that modons with blocking characteristics can result from certain patterns of heating and cooling of the air. Interestingly, the modon idea gives a clue as to how blocks break up. A blocked high might be expected to produce calm conditions and less cloud, which in turn could lead to increased heating and subsequent weakening of the block.

Computer verification

Some success has been achieved in simulating blocking in computer models of the atmosphere. These models have suggested that anomalously warm regions of sea surface contribute to more prevalent blocking. They also give grounds for believing that positive feedback between the ocean and the atmosphere maintains blocking for prolonged periods.

Unfortunately, models are not always able to properly capture small-scale 'triggering' processes involved in the development of blocking. Hence forecasting of blocks remains a very uncertain art.

The atmosphere has a lot of subtlety, and it's eluding us still, by Jove.

Andrew Bell

More about the topic

A survey of blocking mechanisms, with application to the Australian region. P.G. Baines. *Australian Meteorological Magazine*, 1983, **31**, 27–36.

(This issue also contains other papers on blocking, by J.S. Frederiksen, M.J. Coughlan and P.F. Noar, of the Bureau of Meteorology, and D.J. Karoly of Monash University.)