METEOROLOGY

Don't blame the butterfly effect

Is the flap of an insect wing really the main reason for poor weather forecasts, asks Robert Matthews

Sudden storm: new research suggests the butterfly effect is not the main reason forecasters get it wrong – and opens up the possibility of greater accuracy Photodisc

You may not be able to say exactly what it is, but the "butterfly effect" has had an impact on your life at one time or another.

It may have been that five-minute delay getting out of bed that led you to miss your flight, or a brief meeting with an old friend that changed your life. Small things, in short, can have big consequences.

That is the essence of the butterfly effect, a term coined in 1972 by Ed Lorenz, a meteorologist at the Massachusetts Institute of Technology. He had found that the sheer complexity of the Earth's weather system, with its host of feedback loops and interactions, meant even tiny effects could be amplified into huge weather events. Or, as he picturesquely put it, the flap of a butterfly's wing in Brazil could trigger a tornado in Texas.

It is a phenomenon that has cast a long shadow over weather forecasting. That is because every forecast begins with a set of measurements – temperature, pressure and so on – that are inevitably less than perfect. The butterfly effect then amplifies these small errors until they swamp the accuracy of the forecast.

Small wonder, then, that meteorologists – and others dealing with complex systems, such as economic forecasters – have given up hope of making long-term predictions.

But new research now suggests the butterfly effect may not be the main source of trouble after all – a finding that raises the prospect of forecasting becoming substantially more reliable.

According to David Orrell, an expert on the mathematics of complex systems, scientists have been mesmerised by the butterfly effect into overlooking another, more obvious, source of trouble: the basic mathematical model used to make the forecasts.

Every such model is an approximation to the truth: no matter how powerful supercomputers become, they will never capture every nuance of, say, the swirling mass of air over our planet. Inevitably, corners are cut but, until now, it has been an article of faith among most forecasters that the resulting errors are always much less important than those caused by the butterfly effect.

Not so, says Mr Orrell, who has been studying the relative contribution of these two sources of error in computer models used to forecast the behaviour of complex systems, including the Earth's weather. He has found that both sources have their own characteristic pattern of growth, so that careful study of how forecasts go awry can reveal whether the culprit is principally the butterfly effect or simply an inadequate model.

According to Mr Orrell, who was formerly at University College London and is now at the Institute for Systems Biology in Seattle, when the errors are due simply to the butterfly effect, the model's predictions become ever more uncertain over time, but still tend to cluster around the correct result. But if the basic model is fundamentally flawed the predictions do not merely become less precise but also move ever further away from reality.

> Careful study of how forecasts go awry shows whether the butterfly effect or simply an inadequate model is to blame

In a paper due to appear in the International Journal of Bifurcations and Chaos, Mr Orrell makes the distinction precise, allowing forecasters to find out whether they should fret less about the butterfly effect and focus instead on their underlying model. Put simply, Mr Orrell shows that errors due to the butterfly effect grow exponentially, doubling in size over some characteristic timescale – a matter of days in the case of weather forecasts, for example. In contrast, errors due to basic flaws in the model grow according to the square root of time: relatively quickly at first, but then progressively more slowly.

Mr Orrell has applied his methods to a variety of weather forecasting models used by national weather bureaux, with intriguing results. For example, in one widely used model the errors in the first five days of forecasts turned out to be due primarily to flaws in the model, rather than the butterfly effect. This suggests meteorologists are still far from getting the best performance from the model, whose accuracy remains a long way from the ultimate limit set by the butterfly effect.

These findings also have implications for forecasting the effects of global warming – one of the most controversial topics in science today. Such forecasts also rely on computer models and, again, the presumption has been that the chief source of error is due to the butterfly effect. While this rules out detailed long-term prediction, it still allows broad-brush conclusions to be made with some confidence – assuming, that is, that there are no serious flaws in the basic climate model. The dominance of model error found by Mr Orrell's studies suggests this might not be a safe assumption.

So far, the response of the meteorological community to Mr Orrell's findings has been muted. But then, after years of blaming the butterfly effect for mistakes in forecasts, meteorologists may be reluctant to admit that the real culprit may be closer to home than a cabbage white off the Azores.

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