Improving weather forecasts to avert disruptions, damage and disaster

LSE research has helped government and industry to develop ways to better use weather forecasts and improve contingency planning

What was the problem?

Weather has an impact on people, businesses and economies every single day. Even fairly common weather, with no extreme meteorological elements, can produce costly disruptions to the way families, communities and societies function.

Problems can include changes in demand and disruptions to power and water supplies, the production and distribution of food and other basic needs, travel systems, and communication networks such as the Global Positioning Satellite. Even day to day changes in forecasts themselves can have huge impacts.

There is therefore a strong need for more informative weather predictions which enable people with different needs and levels of understanding to plan for and manage their responses to changing weather conditions and to changes in their degree of confidence in the forecast itself.

What did we do?

A team of researchers at the LSE Centre for the Analysis of Time Series (CATS), led by Professor of Statistics Leonard Smith, looked at ways of improving traditional weather forecasting. They interpreted modern "ensembles" of forecasts, as opposed to the traditional single forecast, to better represent today's forward view of what is essentially an uncertain and chaotic system.

Because weather models are imperfect, there are some days when even the ensemble forecasts appear, in hindsight, not to have been accurate. This too is taken into account. The approach is to consider an ensemble as merely a source of information rather than a collection of equally likely scenarios. Smith demonstrated that the European Centre for Medium-Range Weather Forecast's (ECMWF) 51 individual forecast points could be used to produce information regarding the reliability of a single forecast or, alternatively, a probability forecast of a combination of several weather variables. He then looked at developing better ways of communicating both the forecasts of the weather and the probability of those particular forecasts.

"Weather Roulette" – which was developed to literally assess the claim 'I bet I can do better than your forecast' – is a framework for evaluating the performance of forecasts by translating the probabilities into effective daily interest rates (a measure used in finance to show the actual return from a particular interest rate). The exercise starts with an initial investment, such as one euro,

and after every round of betting on the weather outcome, the total value (profit and initial value) is reinvested.

Weather Roulette offers a new approach for communicating the performance and relative value of probabilistic forecast systems. It provides a simple and easy-to-understand framework for evaluating decisions based upon probabilistic weather forecasts. It makes it easier to communicate the results of weather forecasts and can also be used to evaluate the relative performance of different forecasts and the economic value of the forecasts.

Ensembles are particularly useful in situations where small probabilities can lead to large costs or benefits. People with financial skills, such as energy traders and weather centre managers, can easily grasp Weather Roulette and apply it in their own practice-based environments.

What happened?

Official weather forecasters

Smith and CATS have developed significant and long-standing relationships with a number of institutions involved in weather forecasting, including:

- The European Centre for Medium-Range Weather Forecasts (ECMWF), where Smith's work helped them to refine their techniques and methodology
- the US Naval Research Laboratory, where a group is forecasting hurricanes in the Pacific
- the US National Centre for Atmospheric Research, where Dr Hailiang Du, an LSE postdoctoral research officer, is sharing methods and providing a test bed for data assimilations and where observations are being incorporated into a computer model of a real system
- the International Research Institute for Climate and Society and the World Climate Research Programming Working Group on Regional Climate.

> "Prof. Smith and his group's contribution in this area continued throughout the years, and the systems operational today are still benefitting from his research done years ago"
>
> **Roberto Buizza, head of predictability division, European Centre for Medium-Range Weather Forecasts**

Since 2010 ECMWF has incorporated Weather Roulette into its Ensemble Verification Training Course. Weather Roulette is also an essential component of a 'training of trainers' course that has been run by the World Meteorology Organisation's Commission on Climatology over the past five years with representatives from regional climate centres around the world. As of 2014, 150 trainers from seven countries from as far afield as China and South Africa had gone through the training and learned how to use Weather Roulette.

The World Meteorology Organisation has included Weather Roulette as one of its recommended procedures in its *Guidance on Verification of Seasonal Climate Forecasts*, which has been officially disseminated to its 191 member countries and territories.

The United Kingdom Met Office has considered Smith's research in the redesign its 3-month Outlook product, which provides an indication of possible average temperature and rainfall conditions over the UK for the upcoming three months. The Cabinet Office makes this product available on an ongoing basis to managers in both the public and private sectors to enable them to make contingency plans for extreme weather events and potential emergencies.

Impact on industry

Smith and CATS also have a long history of partnership with industry in embedding their research findings in contexts where real-time forecasting is helpful in managing uncertainty and risk. They have focused significant effort on constructing actionable weather information from forecasts on which specific users can take practical decisions. Specific applications have included: road gritting; food sales; horse race-track conditions; crop forecasting; insurance brokerage; energy trading; wind power production; hydrocarbon exploration and production (oil reservoirs and flows); and electricity generation.

Around a third of Smith's students and post-docs are applying this knowledge as employees of organisations, including the Bank of England, Royal Dutch Shell, the Met Office and Risk Management Solutions. Current CATS partnerships are also underway with the UK Department of Energy and Climate Change (DECC) and the Royal National Lifeboat Institute (RNLI).

CATS researchers have been working with the Royal National Lifeboat Institute to identify the weather conditions that tend to cause a high rate of incidents and those that are more likely to result in serious or life-threatening incidents. This work will enable the Institute to make informed planning decisions, such as the positioning of crew or the best time to perform maintenance on the station's equipment.

Smith has worked with EDF Energy to develop methods for forecasting electricity demand, which has helped to reduce risk, manage supply and improve performance.

Metra, the global commercial arm of the New Zealand meteorological service, worked with CATS on the design and marketing of a product called Vantage. This helped energy managers and traders to manage weather-related opportunities and risks and make operational decisions. It led to a new generation of Metra products and services in use worldwide.

Professor Leonard Smith is Director of the Centre for the Analysis of Time Series (CATS) at the London School of Economics and Political Science. Since 1992 he has been a Senior Research Fellow (mathematics) at Pembroke College and Research Associate, Mathematics Institute, University of Oxford, (UK). Professor Smith was active in the formation of strategy for THORPEX and the original

experimental design(s) of climateprediction.net. In recognition of his contributions to mathematically-coherent user-relevant developments in meteorology, the Royal Meteorological Society awarded Professor Smith its Fitzroy Prize in 2003. Professor Smith is currently a member of the ASA Advisory Committee on Climate Change Policy (ACCCP) and a member of the Smith Institute's Scientific Committee.

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