Q+A on Harnessing Butterflies

Q. What's the butterfly effect?

A. The expression "butterfly effect" comes from a celebrated paper by Edward Lorenz in 1972: "Does the flap of a butterfly's wings in Brazil set off a Tornado in Texas?". Think of two planets identical in every way except that on one there is a butterfly. The atmosphere is so unstable that the flap of its wings can be amplified so that it perturbs "eddies", movements a bit bigger. And these perturb eddies a bit bigger until we reach the size of the planet. And it only takes about 10 days for this to happen! This means that although the two planets start off with the same weather patterns, after ten days or so they will be different, after months, they will be totally different.

Q. What does it mean to "harness the butterfly effect"?

A. When meteorologists run their weather models way beyond 10 days – to make for example seasonal forecasts – they know that the due to the butterfly effect – that the storms and other weather will be wrong, yet they hope that taking the average over a whole season (say three months) will correctly predict the average changes. For example, whether next summer will be warmer or cooler than usual.

Q. Where do meteorologists currently draw their information for seasonal forecasts?

The information comes from balloons (600 across the world every 12 hours), it comes from commercial aircraft, from satellites from ground stations, from ships, ocean drifters.

The data are merged into models using sophisticated data assimilation algorithms that correct for some of the errors, fill in holes.

In Canada, it's the CANSIPS (Canadian Seasonal to Inter-annual Prediction System) model. In the US: CFS Climate Forecast System (NOAA).

Q. How successful is the new model (SLIMM: ScaLIng Macroweather Model)?

That depends on several things:

a) it depends your forecast horizon (how far into the future), the further into the future, the worse it gets.

b) it depends on the spatial resolution, the error is smaller for larger regions.

c) It depends on the length of time you average: whether you are forecasting a monthly, seasonal or annual series. Seasonal (3 month) forecasts have less averaging than annual forecast so that a seasonal forecast one year ahead is worse than an annual resolution forecast one year ahead.

Interestingly – due to scale invariance - the skill of three month forecasts three months ahead is the same as for one year forecasts one year ahead.

Annual, globally averaged temperatures can be forecast to an error of 0.09^{o}C compared to about 0.11^{o}C for the GCM's.

This may not seem like a huge improvement, but remember, our result depends on only two parameters and the global annual averaged temperature series over the previous 20 years. In principle we can easily improve the method by adding in more data and parameters. In comparison, the GCM's use huge amounts of data and computer resources.

Preliminary results show that globally, at 500 km resolution, for 3 month temperature forecasts, our method is already 20% better than the conventional method, and in may regions, more than 50% better.

Q. You are taking into the account the butterfly effect to improve this forecasting...
First of all ....what is the butterfly effect?

A. (See above for more details). The butterfly effect is thus a limit to the skill of weather forecasts. Over three month periods we have many weather systems so that we have to harness the randomness.

Q. How will you use butterfly effect to improve seasonal forecasting?

A. First, the effect of the butterflies makes the appearance and disappearance of weather systems over months and years pretty random so that we can model the effect of the weather by using random numbers.

We then use the fact that for any region on the earth, the atmosphere has a preferred "climate state" (ignore climate change here - that's important - but its another story!). The "butterflies" – the random weather - is nudging the temperature higher or lower but the atmosphere "remembers" the nudges that it had received months, years and decades ago: the climate memory turns out to be huge.

The new model uses historical data and exploits this memory to work out the past "nudges" and then put it all together to make the forecast. This ensures that our forecasts converge to the real world.

Q. How successful have your prototypes of this model been so far?

A. We've been quite successful at northern hemisphere and global scales.

For regional scales - e.g. Quebec - we're still evaluating them, but so far the results are quite promising: our results are apparently substantially better than GCM's, especially over land.

-Q. How do their results compare to the current model being used by meteorologists?

A. Seasonal forecasts are notoriously poor, so much so that they are typically given in the form: "next summer the temperature is expected to be warmer than usual" which means that we expect the average temperature from June, July and August to be in the warmest 33.3% of the temperatures on record. Preliminary results show that we can do quite a bit better than the GCM's.

Q. -How much more work is left to do to improve your model?

A. The main problem has been lack of funding. If we can find support in the next few months, progress could be rapid.

Q. Who stands to benefit most from accurate seasonal forecasting?

Hydro Quebec (water management), farmers (agricultural planning), future's markets ($50 billion/yr), disease control (especially malaria), wildfires.

a) Decision Makers
b) Ranchers
c) Water Managers (e.g. Hydro Quebec)
d) Wildfire managers
e) Resource managers
f) Epidemiologists (e.g. Malaria)
g) Insurance, re-insurance industry ($\$1.4\text{x}10^{12}$/yr, 1999)
h) Futures markets (>$\$50\text{x}10^{9}$/yr, 2014)
i) Humanity

Future developments:

a) Improvements in algorithms
b) Regional: single field SLIM, $5^{o}X5^{o}$ resolution
c) Use of other fields to increase accuracy (state vector approach)
d) precipitation, humidity, drought
e) Direct forecasting of indices (insured risk, forest fires, epidemics, sea ice etc.)
f) Extremes
g) Consequences of GHG and other future forcing
h) Seasonal: three month anomalies up to 9 months horizon (annual cycle)
i) Annual scale (including El Nino etc.)
j) Decadal scale: CO2, emissions, future of humanity