University of BRISTOL

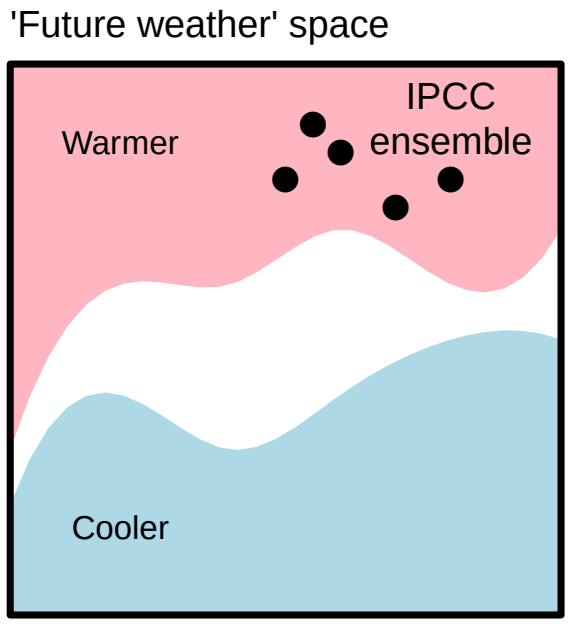
A statistician's viewpoint on weather, climate, and climate simulations

Inaugural lecture - Professor Jonathan Rougier
Monday 29 February 2016

Please note the building's fire exits. There are no planned fire alarms taking place today, so if you hear the alarm sound, please leave via the fire exits and gather at the meeting point outside the Merchant Venturers' Building.

Weather and weather events

- Each possible future weather outcome is a point in ‘future weather’ space.
- A ‘weather event’ is the set of all points with the same feature.
- A future weather simulation is a point in ‘future weather’ space.



Uncertainty and experts

We all have beliefs about the future. For a complicated process like future weather, our policy-makers should consult weather experts.

- *How to quantify uncertainty.*

  When an expert says "$\Pr(A) = 0.3$", it is stating a willingness to bet £0.30 to win £1 if event A occurs, and £0 if it does not.

- *How to rule out bad experts.*

  An expert is coherent exactly when it impossible to force it to lose money on a series of bets it has offered.

  This is a minimum requirement!

There is a powerful theorem about coherent experts . . .

Uncertainty and experts (cont)

Theorem (de Finetti, c1930)

An expert is coherent if and only if its bets obey the rules of probability.

Recollect the rules:

1. $\Pr(A) \geq 0$.
2. If A is certain to occur: $\Pr(A) = 1$.
3. If A and B cannot both occur: $\Pr(A \vee B) = \Pr(A) + \Pr(B)$.

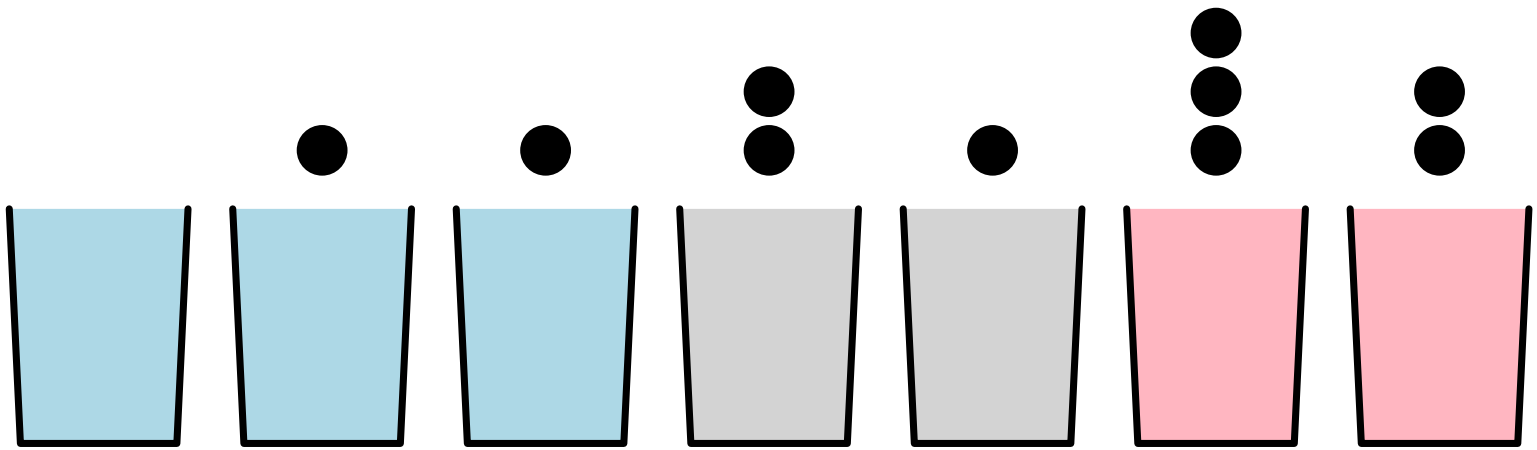
So de Finetti's theorem states:

1. If the expert's bets obey the rules of probability it cannot be made into a sure loser.
2. If the expert's bets do not obey the rules of probability it can be made into a sure loser.

Coherence and buckets

Here is a trivial and suggestive result.
The rules of probability also apply to dropping n balls into buckets, if we define

$$\Pr(A) = \frac{1}{n}\Big(\text{number of balls in buckets of type } A\Big).$$



Weather simulators

Corollary

Weather simulators can be coherent weather experts.

~~How?~~ Proof!

Simulated weather depends on the initial value.

$$\begin{array}{ccccccccccc} x_0 & \longrightarrow & f(x_0) & \longrightarrow & f^2(x_0) & - - & f^t(x_0) & - - & f^{T-1}(x_0) & \longrightarrow & f^T(x_0) \\ & & \| & & \| & & \| & & \| & & \| \\ & & x_1 & & x_2 & & x_t & & x_{T-1} & & x_T \end{array}$$

1750 today 2100

If we select n different choices for x_0 we get n different future weathers. Set

$$\Pr(A) = \frac{1}{n}\Big(\text{number of future weathers which have } A\Big).$$

Weather simulators (cont)

Two important observations:

1. Simulators with larger n's provide more finely-graded probabilities, which must lie in the set

$$0, \frac{1}{n}, \frac{2}{n}, \ldots, \frac{n-1}{n}, 1.$$

   This is obvious :)

2. Simulators whose Year 0 lies further in the past decrease the effect on their probabilities of the way in which the x_0's are selected.

   This is a subtle mathematical insight about the likely existence of a pull-back attractor.

The current state of the art

Our weather experts are coherent, but they are all equally bad.

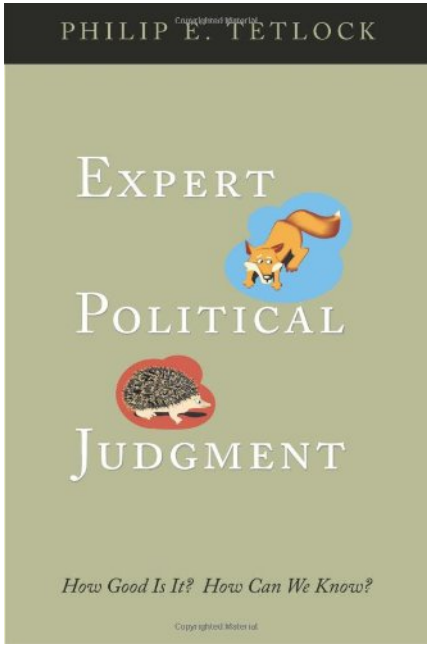
1. Not enough replication: typically $n = 1$ or 'a few'.
2. Not properly 'spun up': typically Year 0 is maybe 1600?

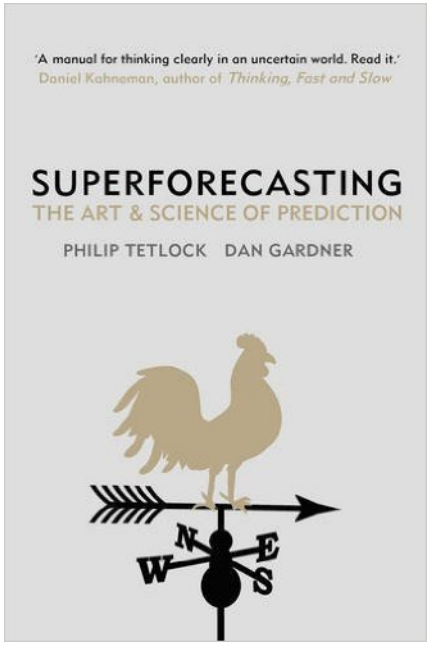
These are both fixable so what is going on?

Explaining vs Predicting: the culture of climate science

. . . I think we'll reserve these highly subjective and potentially inflammatory remarks for audio-only!

Philip Tetlock has the last word on experts





In complex scenarios, most experts forecast no better than chimps. Systematic outperformers can only be found by careful statistical analysis. The outperformers all tend to have similar traits.

We should not abandon our scepticism just because the expert is a computer. 'Good expert' is a relative term.

Finally, my definition of 'climate'

Climate:
A coherent set of bets about weather events.

This definition is consistent with the notion that a 'climate simulator' is an ensemble of $n \geq 1$ future weather simulations with varying initial values, or can be used to construct the same.