Robustness and Uncertainties of Climate Change

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A month does not go by without some new study appearing in a peer-reviewed journal which purports to demonstrate some ill effect that will be caused by global warming. The effects are conditional on global warming being true, which is itself not certain, and which must be categorized and bounded.

Evidence for global warming is in two parts: observations and explanations of those observations, both of which must be faithful, accurate, and useful in predicting new observations. To be such, the observations have to be of the right kind, the locations and timing where and when they were taken should be ideal, and the measurement error should be negligible.

The physics of our explanations, both of motion and e.g. heat, must be accurate, the algorithms used to solve and approximate the physics inside software must be good, chaos on the time scale of predictions must be unimportant, and there must be no experimenter effect. None of these categories is certain.

As an exercise, bounds are estimated for their certainty and for the unconditional certainty in ill effects. Doing so shows that we are *more* certain than we should be.

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Global warming is not important by itself: it becomes significant only when its effects are consequential to humans. The distinction between questions like "Will it warm?" and "What will happen if it warms" are often conflated. For example, when asking how likely are the results of a study of global warming's effects, we are apt to confuse the likelihood of global warming as a phenomenon with what might happen *because* of global warming. Because of this confusion, I want to follow the path to the conclusion of one study whose results state A = "There will be more kidney and liver disease ambulance trips, etc. because of global warming" (1). I start from first principles, and untangle and carefully focus on the chain of causation leading up this claim, and quantify the uncertainty of the steps along the way.

Studies producing results like A imply that $\Pr\{A|AGW\}$ is high, where AGW = "Man-made global warming is significant." However, we really want the unconditional probability of A: $\Pr\{A\} = \Pr\{A|AGW\}\Pr\{AGW\}$. Often, if $\Pr\{A|AGW\}$ is high, it is incorrectly taken as evidence that $\Pr\{AGW\}$ is high. But $\Pr\{A|AGW\}$ can be as close to 1 as you like and AGW can still be absolutely false.

It is trivially true that man—and every other organism—influences his environment and therefore his climate. It is only a question of *how much* and to what extent, if any, AGW is harmful or beneficial, and to what extent its harmful effects can be mitigated, or its benefits exploited. We are not interested in trifles: AGW means discernable, large-scale important effects on climate. To quantify the probability that AGW is true, we must have two necessary items: observations and explanations of those observations. Taken together, these two lead to predictions of future observations. Let OBS = "Our observations are faithful, accurate, and useful" and EXP = "Our explanations are faithful, accurate, and useful." Crudely, $\Pr\{AGW\} \approx \Pr\{OBS\} \times \Pr\{EXP\}$.

There are several layers of uncertainty about observations. The most important are: the kinds, the locations, the timing, and measurement error of observations. Each of these categories is not atomic and may be broken down into subcategories. Thus, $\Pr\{OBS\} \approx \Pr\{Kinds\} \times \Pr\{Locations\} \times \Pr\{Timing\} \times \Pr\{Error\}$. This equation makes two approximations. The first is that the categories are independent. It means, for example, that the location of an observation gives no information about its measurement error. This is obviously false. The measurement error of coral reef temperature reconstructions is different than that of reconstructions using oxygen isotopes found in air bubbles trapped in ice. The second limitation, created as a result of the first, is more problematic: it presumes each of these categories are equally probative on the question of whether OBS is true. Some possible numbers, keeping these limitations in mind, are $\Pr\{OBS\} \approx 0.99 \times 0.9 \times 0.9 \times 0.9 \approx 0.70$.

Our explanations are comprised of: equations of motion as represented in computer code; the physical processes describing heat and radiative transfer, cloud dynamics, etc.; trust that the algorithms used to solve the physical equations converge plus the computer code is error