11 March 2024

Review of
"Towards robust community assessments of the Earth's climate sensitivity"
by Kate Marvell and Mark Webb.
Preprint. Discussion started: 22 February 2024

General Comments

1.   This is an interesting paper, containing both results and discussion of method that are likely to be helpful to the community involved in assessments of climate sensitivity.

2.   I suggest that the paper could be improved substantially by adopting different terminology: by transferring from a terminology appropriate to a subjective interpretation of probability theory (flowing from a subjectivist theory of knowledge) to a terminology appropriate to objective theories of both probability and knowledge. This would involve no changes to the equations or the results, as the mathematics of the probability theory would be unchanged, but it would change the way in which the mathematics is interpreted in terms of its relation to the real world.

3.   Specifically, I suggest the term "belief" (particularly in the term "prior belief") be changed throughout. In most place it could be replaced by "estimate" or "information" or "knowledge". In other places the meaning is different, and it would be better replaced by "assumption". Similarly, I suggest that the term "subjective" is over-used. In most places, what is described as "subjective" is in fact objective, i.e. it is inter-subjectively shared and criticised. In most cases, this sharing and criticism is of the very high standard expected of publications in the scientific literature.

4.   So, if accepted, these comments would imply numerous changes to the text, but ones that could be made without changes to the structure and scientific content of the paper.

5.   A subjective theory of knowledge was widely accepted up to the middle of the 20th century. It was accompanied by a subjective interpretation of probability theory in general and of Bayes theorem in particularly. This interpretation was heavily criticised by Karl Popper in many of his key works. The preference for an objective rather than a subjective, theory of probability is discussed most cogently by Popper in "Realism and the aim of science" (1983). Chapter 1 of Part II is entitled "Objective and subjective probability", and the comments in this review are intended to be consistent with Popper's treatment of these problems. In summarising the difference between these two approaches to probability theory, Popper says (section 7, para 1): "… The subjectivist takes *a* as his hypothesis and *P(a|b)* as our degree of belief in it, whilst the objectivist takes *'P(a|b)=r'* as his hypothesis. (He may or may not believe in it.) …" . (The subjectivist example here stands for the probability that hypothesis *a* is true given evidence *b*, but it applies equally to the case where *a* is the estimate of a quantity and *b* is the observational evidence supporting it.)

If one accepts Popper's criticisms, then the subjective interpretation of probability is both out-moded and unnecessary (although it appears to linger on in some text books on philosophy of science and on statistics).

6.   One could argue that we should not worry about words, because "belief" could be interpreted as "estimate" or "information" or "knowledge" or "assumption". However, I suggest that it is unhelpful to use "belief" in a way that differs radically from its everyday usage. This is epitomised by the biblical story of Doubting Thomas: "Jesus saith unto him, Thomas, because thou hast seen me, thou hast believed: blessed *are* they that have not seen, and *yet* have believed." (John, 20: 29). I suggest that in science, we tend to side with

Thomas rather than with Jesus - we tend to demand the evidence and to avoid belief without it.

7.   Another problem of using the term "prior belief" for an element on the right-hand side of the Bayesian equation is that, if we are consistent, the term on the left-hand side of the equation is then a "posterior belief". However, in this paper and elsewhere, the implication is that the result of the Bayesian process is an objective result, rather than just a belief – that, somewhere along the line, a subjective belief is transformed into an objective estimate. Objective theories of probability avoid this problem.

8.   There is much reference in the paper to "expert judgement" but expert judgement is informed by past experience and its accompanying evidence. Moreover, it is not derived subjectively but through participation in the objective work of the scientific community.

9.   I think the only example of "belief" in this paper is where an "expert" persists in making a judgement despite evidence to the contrary. I think this is rare – usually there is objective evidence for a judgement, even though the evidence is incomplete. A good scientist recognises that it is incomplete and is open to new evidence.

10.   More generally, a good scientist holds his/her views tentatively and hypothetically, recalling that scientific progress takes place through the replacement of one false hypothesis by a better (but probably false) hypothesis. Consequently, a good scientist tries not to "believe" anything but to work via a series of hypotheses and assumptions and their testing.

Detailed Comments

11.   l.7. Here and many other places. "beliefs". See General Comments above.

12.   l.9. Here and many other places. "subjective". See General Comments above.

13.   l.19, eq.(1). What is M_0? - the climate system, a model of the climate system, or the simple energy balance model? If the last, then is the RHS of (1), i.e. including ΔN, different?

14.   l.33: "aerosols". Net cooling in response to aerosols?

15.   l.49 and l.170: "knowledge". See General Comments above.

16.   l.61-622, eq.(3) and following line. If $P(\Theta)$ is a belief, then $P(Y|\Theta)$ must also be a belief (a posterior belief). See General Comment 7 above.

17.   Fig.1(a). Axes need labels.

18.   l..120, equation. This is not very clear. C is not defined.

19.   l.161-162. Sentence "These incorporate expert judgement …". These are normally objective, not subjective, i.e. they are inter-subjectively shared and criticised. This is fundamental in science.

20.   l.166-167: "well-informed scientist". Again, informed by objective information.

21.   I.217-218: "Why do these two distributions not overlap substantially?" They appear to overlap substantially - they are well within each other's one-sigma points.

22.   I.229: "odds". This is another word associated with a subjective theory of probability, and best avoided if you adopt an objective approach.

23.   I.237: "definite". What does definite mean here? Does it mean "certain"? If so, this would not be a scientific statement - uncertainty is all-pervasive in science. If you remove "definite" from this sentence, do you not conclude that state dependence is likely?

24.   I.242: "We are *not* arguing that this is the objectively "correct" way to combine the Last Glacial Maximum reconstructions with historical observations." Given my comment above, it is not clear what you are arguing here.

25.   I.250: "relying on a community of experts". Yes! - this makes it objective - this is how we do science - inter-subjectively shareable and criticisable.

26.   I.263: "assume". Yes - so these are hypotheses (to be tested), not beliefs.

27.   I.286: "prior assumptions: Yes - much better! You can assume something without believing it.

28.   I.290: "accurate". Meaning exact? Unusually, accuracy means a quantification of the uncertainty.

29.   I.294: "belief". At no point in the discussion contained in this paragraph do you need to "believe" anything - you are making certain assumptions or posing certain hypotheses, and then testing their consequences.

30.   I.337: "the prior beliefs of two hypothetical experts". Or you could say just two hypotheses?

31.   I.341: "However, some experts may not be so open-minded …". So, are you are saying that there are closed-minded experts who "believe" things and open-minded experts who make hypotheses?

32.   I.343-345: "Expert C's confidence remains unshaken …" and following sentence. This is fundamental to how science works. You are saying that Expert C is not influenced by evidence and so is not behaving rationally/scientifically. In (good) science, we suspend belief and act tentatively and hypothetically.

33.   I.348-349: "The narrowness of C's prior …". It's OK to have a narrow prior, if all the evidence you have (at present) points in that direction, but it is prudent to assume that there is some possibility (low probability) of a gross error, because of some effect that has not been handled correctly. This leads to a different pdf (e.g. Gaussian + constant). This is a common problem is science - it's called quality control.

34.   I.379: "The beauty of Bayesian methods …". The beauty of objective Bayesian methods is that you don't need to deal in "belief" at all.

35.   l.396, eq.(A3). Superficially, there appears to be a minus sign missing here – required for a Gaussian shape.

36.   Equations at the end of section A1. Again, not clear how this leads to a Gaussian shape.

Editorial Comments

37.   l.242: typo "is are".

38.   l.260, 261.: typos "s(S", "y(K"

39.   A2, line 1: typo "this is method is distinct".