PART 9. SOME SIMPLE GUIDANCE FOR RESEARCHERS[34]

Doing a good job of characterizing and dealing with uncertainty can never be reduced to a simple cookbook. One must always think critically and continually ask questions such as:

- Does what we are doing make sense?
- Are there other important factors which are, as or more important, than the factors we are considering?
- Are there key correlation structures in the problem that are being ignored?
- Are there normative assumptions and judgments about which we are not being explicit?

That said; the following are a few words of guidance to help CCSP researchers and analysts to do a better job of reporting, characterizing and analyzing uncertainty. Some of this guidance is based on available literature. However, because doing these things well is often as much an art as it is a science, the recommendations also draw on the very considerable[35] and diverse experience and collective judgment of the writing team.

Reporting uncertainty

- When qualitative uncertainty words such as likely and unlikely are used, it is important to clarify the range of subjective probability values that are to be associated with those

[34] This section is intended to provide guidance for future CCSP assessment efforts.
[35] Collectively the author team has roughly 200 person-years of experience in addressing these issues both theoretically and in practical analysis in the context of climate and other similar areas.

words. Unless there is some compelling reason to do otherwise, we recommend the use of the framework shown below[36]:

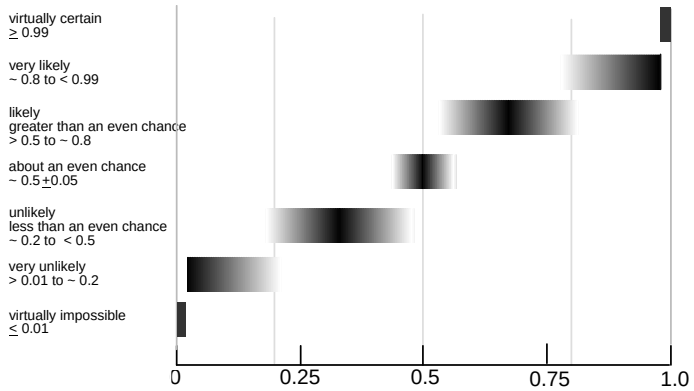

Figure 9.1 Recommended framework for associating common language with subjective probability values

Another strategy is to display the judgment explicitly as shown:

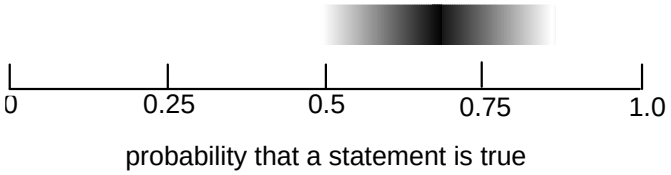

Figure 9.2A method to illustrate the probability that a statement is true

[36] This display divides the interval between 0.99 and 0.01 into 5 ranges, adding somewhat more resolution across this range than the mapping used by the IPCC-WGI (2001). However, it is far more important to map words into probabilities in a consistent way, *and to be explicit about how that is being done*, than it is to use any specific mapping. Words are inherently imprecise. In the draft version of this diagram, we intentionally included significantly greater overlap between the categories. A number of reviewers were uncomfortable with this overlap, calling for a precise 1-to-1 mapping between words and probabilities. On the other hand, when a draft of the United States National Assessment (2000) produced a diagram with such a precise mapping, reviewers complained about the precise boundaries, with the result that in the final version they were made fuzzy (Figure 2.3). For a more extended discussion of these issues see Section 2 of this report.

This approach provides somewhat greater precision and allows some limited indication of secondary uncertainty for those who feel uncomfortable making precise probability judgments.

- In any document that reports uncertainties in conventional scientific format (*e.g.*, 3.5±0.7), it is important to be explicit about what uncertainty is being included and what is not, and to confirm that the range is plus or minus one standard deviation. This reporting format is generally not appropriate for large uncertainties or where distributions have a lower or upper bound and hence are not symmetric. In all cases, care should be taken not to report results using more significant figures than are warranted by the associated uncertainty. Often this means overriding default values on standard software such as Microsoft Excel.
- Care should be taken in plotting and labeling the vertical axes when reporting PDFs. The units are probability density (*i.e.*, probability per unit interval along the horizontal axis), not probability.
- Since many people find it difficult to read and correctly interpret PDFs and CDFs, when space allows it is best practice to plot the CDF together with the PDF on the same x-axis (Morgan and Henrion, 1990).
- When many uncertain results must be reported, box plots (first popularized by Tukey, 1977) are often the best way to do this in a compact manner. There are several conventions. Our recommendation is shown below, but what is most important is to be clear about the notation.

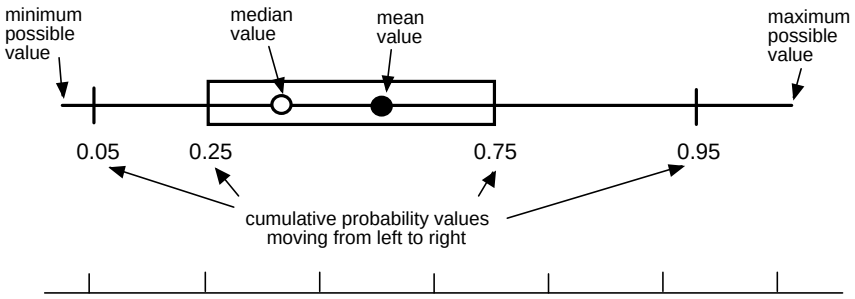

Figure 9.3 Recommended format for box plot. When many uncertain results are to be reported, box plots can be stacked more compactly than probability distributions.

- While there may be a few circumstances in which it is desirable or necessary to address and deal with second-order uncertainty (*e.g.*, how sure an expert is about the shape of an elicited CDF) more often than not the desire to perform such analysis arises from a misunderstanding of the nature of subjective probabilistic statements (see the discussion in Section 1). When second-order uncertainty is being considered, one should be very careful to determine that the added level of such complication will aide in, and will not unnecessarily complicate, subsequent use of the results.

Characterizing and analyzing uncertainty

- Unless there are compelling reasons to do otherwise, conventional probability is the best tool for characterizing and analyzing uncertainty about climate change and its impact.
- The elicitation of expert judgment, often in the form of subjective probability distributions, can be a useful way to combine the formal knowledge in a field as reflected in the literature with the informal knowledge and physical intuition of experts. Elicitation is not a substitute for doing the needed science, but it can be a very useful tool in support of research planning, private decision making, and the formulation of public policy.

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3037 However, the design and execution of a good expert elicitation takes time and requires a
3038 careful integration of knowledge of the relevant substantive domain with knowledge of
3039 behavioral decision science (see discussion above in Section 5).

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3041 • When eliciting probability distributions from multiple experts, if they disagree
3042 significantly, it is generally better to report the distributions separately. This is especially
3043 true if such judgments will subsequently be used as inputs to a model that has a non-
3044 linear response.
3045 • There are a variety of software tools available to support probabilistic analysis using
3046 Monte Carlo and related techniques. As with any powerful analytical tool, their proper
3047 use requires careful thought and care.
3048 • In performing uncertainty analysis, it is important to think carefully about possible
3049 sources of correlation. One simple procedure for getting a sense of how important this
3050 may be is to run the analysis with key variables uncorrelated and then run it again with
3051 key variables perfectly correlated. Often, in answering questions about aggregate
3052 parameter values experts assume correlation structures between the various components
3053 of the aggregate value being elicited. Sometimes it is important to elicit the component
3054 uncertainties separately from the aggregate uncertainty in order to reason out why
3055 specific correlation structures are being assumed.
3056 • Methods for describing and dealing with data pedigree (*e.g.*, Funtowicz and Ravetz,
3057 1990) have not been developed to the point that they can be effectively incorporated in
3058 probabilistic analysis. However, the quality of the data on which judgments are based is

clearly important and should be addressed, especially when uncertain information of varying quality and reliability is combined in a single analysis. At a minimum, investigators should be careful to provide a "traceable account" of where their results and judgments have come from.

- While full probabilistic analysis can be useful, in many contexts, simple parametric analysis, or back-to-front analysis (that works backwards from an end point of interest) may be as or more effective in identifying key unknowns and critical levels of knowledge needed to make better decisions.
- Scenarios analysis can be useful, but also carries risks. Specific detailed scenarios can become cognitively compelling, with the result that people may overlook many other pathways to the same end-points. It is often best to "cut the long causal chains" and focus on the possible range of a few key variables, which can most affect outcomes of interest.
- Scenarios, which describe a single point (or line) in a multi-dimensional space, cannot be assigned probabilities. If, as is often the case, it will be useful to assign probabilities to scenarios, they should be defined in terms of intervals in the space of interest, not in terms of point values.
- Variability and uncertainty is not the same thing. Sometimes it is important to draw distinction between the two but often it is not. A distinction should be made only when it adds clarity for users.
- Analysis that yields predictions is very helpful when our knowledge is sufficient to make meaningful predictions. However, the past history of success in such efforts suggests great caution (*e.g.,* Chapters 3 and 6 in Smil, 2003). When meaningful prediction is not

possible, alternative strategies, such as searching for responses or policies that will be robust across a wide range of possible futures, deserve careful consideration.

- For some problems there comes a time when uncertainty is so high that conventional modes of probabilistic analysis (including decision analysis) may no longer make sense. While it is not easy to identify this point, investigators should continually ask themselves whether what they are doing makes sense and whether a much simpler approach, such as a bounding or order-of-magnitude analysis, might be superior (*e.g.*, Casman *et al.*, 1999).

PART 9 REFERENCES

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