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The value of values in climate science

Standfirst. To date, values are not widely acknowledged or discussed within physical climate science. Yet, effective management of values in physical climate science is required for the benefit of both science and society.

The recently published Working Group I contribution to the Sixth Assessment Report (AR6) of the IPCC acknowledges that values play a role in the construction of climate change information. AR6 recognises that science has its own values including openness, objectivity, and evidence-based thinking. However, it also recognises that social values – fundamental views on what is good, right, and important [1:1.2.3.2] – guide a number of decisions in the “construction, assessment and communication of information (high confidence)" [1: Executive Summary]. This marks a departure from the traditional “value-free ideal” of science, according to which social values should have a limited role in scientific research, while values that are “epistemic” (e.g., precision and accuracy) are seen as legitimately influencing research.

The appeal of the value-free ideal largely rests on its association with objectivity and impartiality. However, the ideal has been challenged by philosophers of science who have demonstrated that social values are integral to research without threatening its objectivity or impartiality. Indeed, ethical evaluation of the societal consequences of error is a marker of good scientific practice [2]. Awareness of values is needed, as unacknowledged assumptions can introduce biases [3, 4]. At the same time, social values should not be allowed to bias research towards a predetermined conclusion [5].

Although the AR6 has opened the door for an open discussion about social values, values are discussed in only two chapters, 1 and 10, and did not propagate into the rest of the report, nor into the Summary for Policymakers. This suggests that despite the open acknowledgement of social values in the construction of climate change information, there might be some difficulty in recognising how this actually occurs.

To aid in developing awareness of values, and to help in ensuring that social values play a legitimate role in research, we provide a number of key messages on the management of values for the climate science community, and present examples of value-judgements in different aspects of climate science (see Boxes 1-3).

Awareness of values

Social values may enter climate change research on many levels such as setting the aim or purpose of studies [6], formulating research questions [7], constructing and evaluating models [8], and communicating results [3]. Many such steps in research are mediated by choices, so developing an awareness of values can be aided by developing an awareness of choices. Different sets of choices may prioritise and thereby advantage the interests of some stakeholder groups over others [9].

To illustrate how values guide choices, consider climate model development [8]. The initial purposes of any climate modelling study reflect some interests – be they those of modellers or the funding bodies. Such interests in turn reflect values. The prioritisation to study one region over another, or near-term versus long-term climate change, for example, reflects the priorities and values of either the researchers or the funding bodies.

However, the influence of values is not limited to the choice to prioritise one aim over another; they can influence the model's subsequent construction and evaluation, too. For example, the value-laden purposes of models may influence the choice of which components and relationships to model or not to model. As to the evaluation of the model against observations, the initial purposes and priorities can have an impact on what counts as a good enough fit with observations [8]. Where results from several models are integrated, values affect model selection and/or weighting (see Box 1). Furthermore, important scientific debates about methodologies can sometimes ultimately concern values (e.g., risk preferences in event attribution, Box 2, or more broadly in climate change itself, which have implications for the representation of uncertainty [10]).

Developing an acute awareness of how methodological choices and broader aims advantage different interests forms the first step in effectively managing the influence of values.

Careful incorporation of values

After developing an awareness about values associated with different choices in research, this information needs to be dealt with. At a minimum, values should not be allowed to direct scientific inquiry towards a predetermined conclusion [2, 3, 5]. In a more positive vein, one of the central recommendations in the philosophical literature has been to foster diversity. Diversity is important, because value judgments that are shared by a dominant majority can be rendered invisible [11, 12]. Where researchers come from a diverse set of perspectives, there is the opportunity to achieve greater objectivity by incorporating different perspectives, as is for example done by the IPCC's increasing inclusion of scientists from developing countries.

Furthermore, it has been proposed that value-judgments should be made transparent; they should reflect social and ethical priorities; and be scrutinised by engagement with multiple stakeholders [3]. However, a number of these proposals require further contextualisation to climate science, since only some [e.g. 13, 14] are tailored to specific practices of climate science (for example climate services, see Box 3). To name but two obstacles to the issued guidelines, stakeholders such as future generations cannot be engaged with, and there is the possibility of reasonable disagreement between stakeholders. To make philosophers' more general recommendations on the management of values more relevant to climate science, the engagement of the climate science community would be helpful.

Bridges to the humanities

Managing social values requires reflecting on the relationship between science and society, which is studied by many disciplines in social sciences and the humanities. Engaging with this research can support the physical climate science community in navigating their role as experts in a field of high societal relevance. Workshops and focused meetings provide a good opportunity to increase interdisciplinary collaboration and training for physical scientists on value-judgments and the science-

society relationship. Reflecting about social values should not be siloed to the humanities and social sciences, but be part and parcel of the practice of physical scientists. For example, recognizing that values cannot be separated from physical science (as in part already noted by the IPCC's AR6 [1]) would pave the way for substantial progress in managing values in climate science.

Much could be gained by making the topics of values and the relationship between science and society part of science education. Allowing students the space to reflect on the relevant humanities literature would promote more nuanced and effective practices. This could be achieved by inclusion of a component on ethics and philosophy of science in degrees such as physics, meteorology, or computer science, as is already done by some institutions.

Value-judgments in communication

There is no neutral way of framing information, as framing always involves decisions on what to include or exclude [15]. For example, the interpretation of statistics can be critically value-influenced and requires both statistical and value literacy [16]. Furthermore, when scientific findings are communicated to policymakers or the public, communicators should be aware of the values of the audience to build a bridge between those values and the scientists' framing of the message [17].

Values are also relevant when thinking of scientists' responsibility to inform the public. Scientists may feel obliged to refrain from expressing societal values in line with the principle of the IPCC to be policy-relevant yet policy neutral. Scientists also may fear that colleagues or the public may perceive this as biased or as activism. However, we recommend that scientists, as possessors of specialist knowledge, should first and foremost serve the public interest. Although there is a range of ways scientists may position their expertise in relation to policy [18], they should not restrain themselves from warning about threats that have a societal impact [19].

Scientific research cannot be value-free, and climate science is no exception. To ensure the best support for decision-making within climate research, it is critical to develop an awareness of the influence of values on scientific practices and communication. This goes beyond applied aspects such as climate services (Box 3)

and extends to the more foundational aspects of physical climate science as well. This can be achieved by reflection, considering the suitability of strategies such as transparency and diversity, cross-disciplinary cooperation, and education. Although the philosophical literature suggests some guidelines on how social values can be better managed in science, work remains to be done in contextualizing such recommendations for climate science, which would be helped by the physical climate science community's engagement. Now that the IPCC's AR6 WGI report has opened the door for acknowledging social values in climate science, we await scientists to step through it.

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Author contribution statement

The comment originated from a workshop, organised by SU, KP, FB, and PWS, in which all co-authors took part. KP wrote most of the manuscript, and led and coordinated the discussion, assisted by SU, with contributions from FB, PWS and all co-authors. SU drafted the text boxes.

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REFERENCES

[1] Chen, D., et al. in: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. Masson-Delmotte, V., et al.) (Cambridge University Press, in Press.)

[2] Douglas, H.E. *Science, Policy, and the Value-Free Ideal*. (University of Pittsburgh Press, 2009)

[3] Elliott, K.C. *A Tapestry of Values*. (Oxford University Press, 2017).

[4] Douglas, H. in *The Oxford Handbook of Philosophy of Science* (ed. Humphreys, P.). (Oxford University Press, 2016). https://doi.org/10.1093/oxfordhb/9780199368815.013.28

[5] Anderson, E. *Hypatia*, **19**(1), 1–24 (2004). https://doi.org/10.1111/j.1527-2001.2004.tb01266.x

[6] Intemann, K. Eur J Philos Sci, **5**(2), 217–232 (2015). https://doi.org/10.1007/s13194-014-0105-6

[7] Winsberg, E., Oreskes, N., & Lloyd, E., *Stud. Hist. Philos. Sci. Part A,* **84**, 142–149 (2020). https://doi.org/10.1016/j.shpsa.2020.09.003

[8] Parker, W.S., & Winsberg, E. Eur J Philos Sci, **8**(1), 125–142 (2018) https://doi.org/10.1007/s13194-017-0180-6

[9] Brown, M.J. *Science and Moral Imagination: A New Ideal for Values in Science*. (University of Pittsburgh Press, 2020).

[10] Shepherd, T.G., Boyd, E., Calel, R.A. et al. *Climatic Change* **151,** 555–571 (2018). https://doi.org/10.1007/s10584-018-2317-9

[11] Jebeile, J. *Social Epistemology*, **34**(5), 453–468 (2020). https://doi.org/10.1080/02691728.2020.1779380

[12] Longino, H. *Science as social knowledge : values and objectivity in scientific inquiry*. (Princeton University Press, 1990).

[13] Parker, W.S., & Lusk, G. *Bull Am Meteorol Soc*, **100**(9), 1643–1650 (2019). https://doi.org/10.1175/BAMS-D-17-0325.1

[14] Lusk, G. *Philosophy of Science*. (2020). https://doi.org/10.1086/710803

[15] Mair D., et al, *Understanding our political nature: How to put knowledge and reason at the heart of political decision-making*. (Publications Office of the European Union, 2019) https://doi.org/10.2760/374191

[16] Shepherd, T.G. *Climatic Change* (in press). https://doi.org/10.1007/s10584-021-03226-6

[17] Corner, A. *A new conversation with the centre-right about climate change: Values, frames and narratives*. (Climate Outreach & Information Network, 2013). https://climateoutreach.org/reports/a-new-conversation-with-the-centre-right-about-climate-change/

[18] Pielke, R. *The Honest Broker: Making Sense of Science in Policy and Politics*. (Cambridge University Press, 2007).

[19] Oreskes, N. *Daedalus*, **149**(4), 33–45 (2020). https://doi.org/10.1162/daed_a_01815

[20] Winsberg E., in *Climate Modelling. Philosophical and Conceptual Issues* (eds. Lloyd, E.A., and Winsberg, E.). (Palgrave Macmillan, 2018).

[21] Lee, J.Y., et al. in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. Masson-Delmotte, V., et al). (Cambridge University Press. In Press.)

[22] Cramer, W., et al, in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. Masson-Delmotte, V., et al). (Cambridge University Press. In Press.)

[23] Seneviratne, S.I. et al. in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. Masson-Delmotte, V., et al). (Cambridge University Press. In Press.)

[24] Shepherd, T.G. *Nature Geoscience*, 7(10), 703–708 (2014). https://doi.org/10.1038/ngeo2253

[25] Ranasinghe, R., et al. in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. Masson-Delmotte, V., et al). (Cambridge University Press. In Press.)

[26] Doblas-Reyes, F.J, et al. in *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (eds. Masson-Delmotte, V., et al). (Cambridge University Press. In Press.)

[27] Adams, P., et al. Toward an ethical framework for climate services: A white paper of the Climate Services Partnership Working Group on Climate Services Ethics. (CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), 2015). https://hdl.handle.net/10568/68833

Textbox 1: Values in multi-model based assessments

A great number of research questions in climate science are answered by combining results from global climate model simulations within a multi-model framework and/or by their integration with observations. Winsberg [20] argues that an opaque, inscrutable tapestry of values lies behind such results, because of the models' size and complexity, distributed epistemic agency, and generative entrenchment of methodological choices. Any multi-model based assessment must moreover deal with the questions of which models to include, and how to combine them [21, Box 4.1]. The extremes range from including all available models, e.g. in a CMIP context, and applying a principle of one-model-one-vote, to selecting a single or very few flagship models. The underlying question of what is a good (enough) model is made explicit in model selection, and implicit in model weighting, and relies on value-laden choices of metrics that may favour one spatial scale or region over another, or one process over another, or one stakeholder interest over another. This applies also to the AR6 approach of using a constrained ensemble of emulators for future projections, where the constraints are chosen to be based on simulation of past warming, ECS, and TCR.

Textbox 2: Values in event attribution

Event attribution in its broadest sense is the evaluation of the contribution of causal factors to observed events [22]. Two different methodological approaches to event attribution in climate science have been at times fiercely debated: the so-called probabilistic approach and the storylines approach, which occupy different positions on a spectrum of what level of conditioning on the meteorological circumstances is appropriate [23:11.2.3]. A focus of debate has been the treatment of uncertainty in the dynamic response to anthropogenic forcing, given that uncertainty in the thermodynamic response is generally much lower [24]. It has been argued that the two sides fundamentally disagree about risk preferences [7]. The proponents of the storylines approach are more concerned with false negatives (i.e. falsely rejecting or underestimating anthropogenic influence on an event), and their methodology is supposedly less prone to this type of error, while it is the opposite for the probabilistic approach and its proponents. Either risk preference, and hence preference for either methodology, is argued by Winsberg et al. [7] to be motivated by values, in particular by the balance between valuing epistemic confidence and informativeness.

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Textbox 3: Values in climate services

Climate services provide climate information to assist decision-making, aiming to support adaptation, mitigation, and risk management decisions [25]. This can be influenced by the values of all parties involved [26]. Maximising the fit of the information provided to the needs of the service users includes in particular the consideration of the users' value system [27, see also 14]. Parker and Lusk [13] argue that a significant and feasible component is to match the risk preferences of the analysis to those of the users. This can be done by learning which types of errors the users find particularly undesirable; recognising methodological choices that differ in the risk of these errors; and making those choices in consultation with the users [ibid.]. For on-demand climate services, the authors suggest the use of clear warnings about product limitations and uncertainties in anticipation of various risk preferences, which allow for user-customisation at the point of service. Otherwise, they propose the prioritisation of those user groups that might suffer especially severe harms and have limited access to climate information [ibid:1647], and call for clear communication of which choices are influenced by values and how.

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