Chapter 14
Ethics and Accountability of Science in Action

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1 Introduction

Ethics in climate and environmental science involve principles such as integrity, objectivity, and impartiality (Kriebel et al. 2001). The high stakes involved in addressing climate change and environmental degradation make science ethics and accountability very high priority (Grubb 1995). Scientists have a responsibility to ensure that their work is conducted with the highest ethical standards and that the findings are reliable, transparent, and accountable to the wider scientific community and society at large (Von 2013). Scientists must adhere to rigorous research practices, including data collection, analysis, and reporting, to ensure the accuracy and

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validity of their findings. This is essential in shaping policy decisions and public discourse surrounding climate change and environmental issues. Ethical considerations must ensure that scientific research is not influenced by vested interests or political agendas, and that the results are communicated in a clear and unbiased manner (Krimsky 2004).

Although most of the time, scientists are not the party who are accountable in specific applications, they should be responsible for the methodologies and data used in their research, as well as the implications and potential limitations of their findings (Brewerton and Millward 2001). This involves robust peer review processes, open access to data and methodologies, and clear documentation of research processes. Accountability ensures that scientific work can be replicated, validated, and built upon by other researchers, fostering a culture of transparency and trust in the scientific community. Moreover, accountability ensures that scientists are held responsible for any potential conflicts of interest or ethical breaches, reinforcing the integrity of the field. Examples of the need for ethics and accountability in climate and environmental science can be found in controversies surrounding climate change denial, manipulation of scientific data, or conflicts of interest in research funding (Sarewitz 2004). These instances highlight the importance of maintaining scientific integrity and ensuring that ethical principles are upheld. By embracing ethics and accountability, scientists and researchers can contribute to the development of evidence-based policies and solutions that address climate change and environmental challenges effectively.

The absence of ethics and accountability in climate science will have disastrous consequences that will undermine the integrity and impact of scientific research as its least impact (Gardiner 2010). Without ethical standards and accountability measures, trust in the scientific community and its findings can be eroded. This will inevitably lead to skepticism and public distrust of scientific information on climate change and environmental issues. Without trust, it becomes challenging to mobilize public support for necessary actions and policy changes. There is a risk of misinformation and manipulation of scientific data. This can occur through deliberate distortion or suppression of research findings to serve vested interests or ideological agendas. Such actions can mislead the public, policymakers, and other stakeholders, hindering efforts to address climate change and environmental challenges effectively. Also ethical lapses and lack of accountability can undermine evidence-based policymaking. When scientific research is not conducted with integrity and transparency, policymakers may make decisions based on flawed or biased information, which can result in the implementation of ineffective or insufficient policies that fail to address the urgency and complexity of climate and environmental issues (Glynn et al. 2017). On cost-wise aspects, without ethical standards and accountability, resources may be misallocated or wasted on research that lacks scientific rigor or is influenced by conflicts of interest. This can hinder progress in developing viable solutions or impede the advancement of more robust scientific investigations. Ultimately, limited resources are not optimally utilized to tackle climate change and environmental problems. Last but not least, it can tarnish the reputation of the scientific community as a whole. Instances of ethical breaches or scientific misconduct can lead to the loss of credibility and public confidence in the scientific enterprise. This can have long-term consequences, impeding collaboration, hindering funding opportunities, and damaging the reputation of climate and environmental scientists.

Beside the ethical concerns on the science side, there are many more on the stakeholder or decision-maker side. Ethical and accountability concerns among stakeholders and decision-makers themselves can create barriers to the use of science advice in climate and environmental decision-making (Rickards et al. 2014). Stakeholders involved in decision-making processes may have personal or financial interests that could influence their judgment or compromise their objectivity. For example, a decision-maker who holds shares in a company that could be affected by a proposed environmental policy may be biased in their decision-making process (Hedberg and Ullabeth 2004). Then there are so many lobbying and influencing activities which means powerful interest groups or industry lobbyists may exert undue influence on decision-makers, potentially leading to the manipulation or distortion of scientific advice. This can undermine the integrity and impartiality of the decision-making process. Examples include instances where in history there are stubborn traditional energy companies that have influenced climate change policies to protect their business interests. If decision-making processes lack transparency, it becomes difficult to hold stakeholders accountable for their actions. The lack of transparency can hinder public scrutiny and the ability to identify conflicts of interest or ethical lapses. Decision-makers may prioritize short-term political gains over long-term environmental sustainability. This can result in the neglect or suppression of scientific advice that contradicts political objectives. Political considerations can undermine the credibility and effectiveness of science advice, compromising its utilization in decision-making. They may be influenced by public sentiment that is misinformed or driven by populist narratives which can result in the rejection or distortion of scientific advice that challenges popular opinions or beliefs (Roberts et al. 2002). In such cases, decision-makers may prioritize their own political survival or public support over evidence-based decision-making. Addressing these ethical and accountability concerns requires the establishment of robust governance mechanisms, transparency in decision-making processes, and the enforcement of ethical codes of conduct. Independent oversight bodies and mechanisms to identify and manage conflicts of interest are essential. Creating a culture of accountability and promoting science literacy among decision-makers can enhance their understanding of the importance of utilizing science advice in an ethical and accountable manner.

This chapter aims to shed light on the requirements and challenges related to ethics and accountability in environment science. It provides a comprehensive examination of the ethical considerations that stakeholders and decision-makers should address when utilizing scientific advice to tackle climate and environmental challenges. By highlighting the potential roadblocks and ethical concerns, this chapter serves as a guide to navigate the complexities and ensure the effective utilization of science-guided advice. It will identify the requirements for ethics and accountability across different stakeholders involved in climate science and decision-making processes. It emphasizes the need for transparency, integrity, and independence in the utilization of science advice. By addressing conflicts of interest, lobbying influences, and promoting transparency, decision-makers can overcome ethical concerns and establish a robust framework for incorporating science advice into policy-making (Boston and Lempp 2011). This chapter will explore cases where conflicts of interest have hindered effective decision-making, such as the influence of the fossil fuel industry on climate policies. By learning from these examples and developing strategies to address ethical concerns, decision-makers can ensure that scientific advice is used in an unbiased and accountable manner. Furthermore, it may delve into the importance of public perception, political considerations, and the role of transparency in building trust and public confidence in the decision-making process.

2 Needs of Ethics and Accountability for Actionable Science

2.1 The Needs from the Scientists' Side

On the scientist side, several key needs and considerations revolve around transparency, data sharing, scientific integrity, peer review, and communication (Tennant 2018). Scientists should strive for transparency in their research by clearly documenting their methods, data sources, and analysis techniques. This includes making research data, models, and code openly available for scrutiny and replication. Transparent practices promote accountability and allow for independent verification and validation of scientific findings. Sharing data among scientists and stakeholders is crucial for collaboration, verification, and replication of research findings. Open data policies like FAIR, data management plans, and standardized data formats can facilitate data sharing and enable reproducibility (Alnaim and Sun 2022). For instance, initiatives like the Intergovernmental Panel on Climate Change (IPCC) and the Global Climate Observing System (GCOS) (Plummer et al. 2017) promote data sharing and collaboration in climate science. The relationship between data FAIRness (Findable, Accessible, Interoperable, and Reusable) and scientific integrity in climate science is closely intertwined. FAIR data principles can greatly help the science community uphold scientific integrity by ensuring that data used in research is reliable, transparent, and accessible for scrutiny and validation. They will enhance transparency, promote collaboration, and enable the replication and validation of research findings. By adhering to these principles, scientists can ensure that their research is conducted with rigor, transparency, and accountability.

(1) *Ethics for Traditional Climate Science*

Maintaining scientific integrity is essential for upholding ethical standards in climate science (Edwards and Roy 2017). This involves conducting research with objectivity, rigor, and honesty. Scientists should adhere to sound scientific practices, avoiding biases, conflicts of interest, or the manipulation of data or results to fit preconceived narratives. Rigorous peer review processes, professional codes of conduct, and institutional oversight help ensure scientific integrity. Peer review is a critical component of the scientific process, providing a mechanism for quality control and ensuring that research meets rigorous scientific standards. Peer review helps identify and address any ethical concerns or flaws in study design, methodology, or analysis. It ensures that scientific findings are robust, reliable, and free from bias. Scientists strive to approach their research without personal biases or predetermined conclusions. They employ robust methodologies, rigorous data analysis techniques, and statistical tools to ensure objective interpretation of results. Objectivity in climate science can avoid confirmation bias or cherry-picking data that supports a particular viewpoint. By maintaining objectivity, scientists can contribute to the accuracy and reliability of research findings. For instance, in climate modeling, scientists aim to develop models that accurately represent the physical processes involved in climate change without favoring any specific outcome (Hallegatte 2009). These models undergo extensive validation and evaluation to ensure they objectively capture the complexity of the Earth's climate system. In paleoclimatology, researchers analyze ice cores, tree rings, and other proxy data to reconstruct past climate conditions. Rigorous sampling techniques, precise laboratory measurements, and adherence to established calibration methods can be used to ensure the accuracy and reliability of the reconstructed climate records (Lowe 2001). Scientific integrity also demands honesty in reporting research findings. Scientists should accurately and transparently communicate their methods, results, and limitations. It is essential to avoid data manipulation, selective reporting, or exaggeration of findings. Meanwhile, open and honest discussions of uncertainties and limitations help prevent misinterpretation and maintain public trust in climate science. The Intergovernmental Panel on Climate Change (IPCC) reports must undergo a rigorous review process involving thousands of expert reviewers. The transparency and honesty in the reporting of uncertainties ensure the credibility and integrity of the assessments.

Effective communication of scientific findings is also important for engaging with stakeholders, policymakers, and the public. Scientists should communicate their research in an accessible and transparent manner, emphasizing the uncertainties and limitations associated with their findings. Open dialogue and collaboration with stakeholders can help address ethical concerns, incorporate diverse perspectives, and build trust in the scientific process. Scientists are always encouraged to strive to communicate their research in a way that is accessible to a wide range of audiences. This involves using clear and jargon-free language, visual aids such as graphs and diagrams, and relatable examples to convey complex scientific concepts (Vai and Sosulski 2015). By making their findings understandable to policymakers, stakeholders, and the public, scientists can facilitate informed decision-making and promote the adoption of evidence-based policies. For example, it would be a great channel for climate scientists to often engage in science communication through public lectures, media interviews, and online platforms, where they can use simple language and visualizations to explain the causes and impacts of climate change, helping the general public grasp the scientific concepts involved.

(2) *Ethics for AI*

Very different from the traditional climate research approaches (such as physics modeling and remote sensing), AI has a whole new set of shining tools, which requires additional caution on its ethics when being adopted in practice. The requirement for AI ethics presents unique considerations compared to traditional science ethics due to the distinctive characteristics of AI technologies (Hwang et al. 2020). AI can be susceptible to biases embedded in the data or the algorithms themselves, which can lead to unfair outcomes. Climate and environment scientists should be aware of the potential biases in their data collection and model development processes, ensuring that their AI models are fair and unbiased. They need to be proactive in identifying and mitigating biases, employing techniques like data augmentation, fairness metrics, and algorithmic auditing to promote fairness and mitigate discrimination. For instance, the use of satellite imagery and remote sensing data for environmental monitoring can inadvertently perpetuate biases if certain areas or populations are systematically excluded. Ethical practitioners work toward improving data collection methods and ensuring equitable representation in training datasets.

Unlike traditional scientific methods where the processes and results are often more transparent, AI models can be complex and opaque, making it challenging to understand their decision-making processes. Climate and environment scientists should prioritize explainability and transparency in their AI models, employing techniques such as interpretable machine learning, model visualization, and documentation to ensure that stakeholders can understand and trust the outputs of AI systems (Ganji and Lin 2023). Besides, AI often relies on large-scale data collection and processing, raising concerns about data privacy and security. Climate and environment scientists should ensure that they handle personal and sensitive data in a responsible and ethical manner (Hodson 2003). Implementing robust data protection measures, obtaining informed consent, and anonymizing or aggregating data whenever possible are essential steps to safeguard privacy in AI applications.

In addition, AI systems can have profound non-controllable impacts, therefore there is a pressing need to establish clear lines of accountability and responsibility (Rivas et al. 2023). Climate and environment scientists should consider the potential consequences and unintended effects of AI applications, conducting thorough impact assessments and incorporating mechanisms for ongoing monitoring, evaluation, and accountability (Rillig et al. 2023). This includes regular audits, adherence to ethical guidelines, and mechanisms for addressing ethical concerns raised by stakeholders. Meanwhile, the development and deployment of AI technologies require collaboration and multidisciplinary approaches. Climate and environment scientists should engage with a wide range of stakeholders, including policymakers, industry leaders, and civil society organizations, to ensure that ethical considerations are integrated into the entire AI lifecycle. Collaborative governance frameworks, codes of conduct, and transparency initiatives can help foster responsible and inclusive AI practices.

(3) *Ethics for Human Subject Research*

Some climate science will involve studies that involve human participants or animal subjects. Ethical considerations in these cases include obtaining informed consent from participants, ensuring participant privacy and confidentiality, and minimizing harm or suffering to animals. Research ethics boards and institutional review processes oversee the ethical treatment of human and animal subjects. When conducting surveys on the impacts of climate change on vulnerable communities, researchers must obtain informed consent from participants and protect their privacy and confidentiality. Obtaining informed consent is a required task in human subject research. Participants should have a clear understanding of the study's purpose, procedures, potential risks, and benefits, and voluntarily provide their consent to participate. For example, in studies involving interviews or surveys with individuals impacted by climate change, researchers should ensure participants understand the purpose of the research, how their responses will be used, and any potential risks associated with participation. On the other hand, respecting privacy and confidentiality need to be mandated for all the participating researchers in human subject research and should ensure that participants' personal information is protected and kept confidential. For instance, in studies that involve collecting sensitive information about individuals' experiences with environmental hazards, researchers must handle the data with strict confidentiality and anonymize the data to prevent the identification of participants.

Researchers must conduct a thorough risk-benefit assessment to ensure that the potential risks to participants are minimized, and the benefits of the research outweigh the potential harms. For example, in studies that involve fieldwork in hazardous environmental conditions, researchers should implement appropriate safety measures to mitigate risks to participants' health and well-being (Howe 2022). Special care must be taken when involving vulnerable populations in research, such as children, indigenous communities, or marginalized groups. Researchers should ensure that these populations are not exploited and that their rights and interests are protected. In studies that involve working with vulnerable populations affected by climate change, researchers should engage in meaningful consultation and collaboration, respecting their cultural values, knowledge systems, and rights.

Other requirements include obtaining ethical approval from an Institutional Review Board or similar ethics committees. The IRB ensures that the research design and protocols adhere to ethical guidelines and regulations. Researchers should follow the specific guidelines set by their institutions and obtain the necessary approvals before starting their research projects. Real-world research projects, such as those investigating the impacts of climate change on vulnerable communities or examining the health effects of environmental pollution, often adhere to rigorous ethical standards, such as the studies conducted by the World Health Organization (WHO) on the health impacts of environmental factors prioritize ethical considerations in their research protocols.

2.2 The Needs from the Stakeholders'/Users' Side

Stakeholders, who are standing on the other side of the bridge, basically have similar ethical requirements for the science findings. They need transparency in the scientific process to build trust and confidence in the results. They should have access to information about data sources, methodologies, and potential biases or limitations. For example, when receiving the results from the climate models, stakeholders rely on transparent documentation and disclosure of assumptions to understand the basis of projections and make informed decisions (Süsser et al. 2022). Ethical considerations require involving diverse stakeholders and considering their values, needs, and interests in decision-making processes. This includes engaging marginalized communities, indigenous groups, and vulnerable populations to ensure their voices are heard and their rights are respected. For instance, environmental impact assessments must include affected communities in the decision-making process and address any disproportionate impacts.

At the same time, users also expect fairness and equitable outcomes in the distribution of risks, benefits, and burdens associated with climate and environmental actions. Ethical considerations require addressing social, economic, and environmental justice issues. For example, renewable energy projects should consider the potential impacts on local communities, such as land use conflicts or displacement, and ensure fair compensation and benefits (Knox et al. 2022). Users normally can recognize the importance of long-term sustainability and expect science results to contribute to sustainable development. This involves considering the impacts on ecosystems, future generations, and the global commons. For instance, in fisheries management, ethical considerations require balancing short-term economic interests with the long-term health and productivity of fish stocks. Also, as independent individuals, users should adopt science results responsibly and avoid misinterpretation, manipulation, or cherry-picking of data to fit their own agendas. Ethical considerations involve using science to inform evidence-based decision-making and policy development. For example, in climate policy debates, stakeholders should rely on a comprehensive understanding of scientific consensus rather than selectively citing individual studies.

3 Current Law, Policy, and Practice in Society

Law and policy together shaped the frameworks to shape the practice of science in our daily lives. These frameworks provide the legal and regulatory structures that govern activities related to climate change mitigation, adaptation, and environmental protection. They also influence the practices and behaviors of individuals, organizations, and governments in addressing climate and environmental challenges.

3.1 International Agreements and Treaties

International agreements and treaties form the foundation of global efforts to address climate change and protect the environment, for example, the Paris Agreement, which aims to limit global temperature rise and enhance climate resilience, and the Convention on Biological Diversity, which focuses on the conservation and sustainable use of biodiversity. These agreements set the overarching goals and principles that guide national and regional policies and actions. Another recent example is the Kigali Amendment, adopted in 2016, which extends the scope of the Montreal Protocol to include the phase-down of hydrofluorocarbons (HFCs), which are potent greenhouse gases. The Montreal Protocol, established in 1987 (Jansen et al. 2023), aims to protect the ozone layer by phasing out the production and consumption of ozone-depleting substances. HFCs are commonly used as refrigerants in air conditioning and refrigeration systems. While they do not deplete the ozone layer, they have a high global warming potential. The Kigali Amendment sets out a schedule for the gradual reduction of HFCs, with developed countries taking the lead in phasing down HFC production and consumption, followed by developing countries. By reducing the use of HFCs, the Kigali Amendment is expected to make a significant contribution to global efforts to mitigate climate change. The amendment is an example of international cooperation to address a specific climate issue through a legally binding agreement. It reflects the recognition of the global community that coordinated action is necessary to reduce greenhouse gas emissions and limit the warming of the planet. The amendment has gained widespread support, with over 100 countries ratifying or acceding to it as of 2021.

3.2 National Legislation and Regulations

Governments enact laws and regulations to address climate change and environmental issues at the national level. These laws cover a wide range of aspects, such as emissions reductions, renewable energy targets, land and water management, pollution control, and conservation measures. For instance, the Clean Air Act in the United States sets emission standards for pollutants (Belden 2001), while the Renewable Energy Act in Germany promotes the development of renewable energy sources. National policies and regulations provide the legal framework for actions and investments in climate and environmental initiatives. In terms of ethical and accountability implementation, the Clean Air Act establishes a framework that emphasizes transparency, scientific integrity, and public participation. The law requires the Environmental Protection Agency (EPA) to set National Ambient Air Quality Standards (NAAQS) for pollutants that are harmful to human health, such as ozone, particulate matter, carbon monoxide, and sulfur dioxide (Bachmann 2007). These standards are based on scientific research and undergo rigorous review and public comment processes to ensure their integrity and accuracy. The EPA is accountable for enforcing these standards and monitoring air quality across the country. The Clean Air Act also incorporates mechanisms for accountability and compliance. It requires states to develop State Implementation Plans (SIPs) (Reitze 2004) outlining strategies and measures to achieve and maintain air quality standards. The EPA oversees the implementation of SIPs and can take enforcement actions against states or industries that fail to meet the required standards. Additionally, the CAA includes provisions for citizen suits, allowing individuals and organizations to hold violators accountable through legal actions.

However, the ethical considerations in the enforcement of the Clean Air Act involve the protection of vulnerable populations, environmental justice, and the equitable distribution of the benefits and burdens of pollution control measures. The EPA is required to consider the potential impacts of air pollution on marginalized communities and ensure that regulations are not disproportionately affecting disadvantaged groups. Stakeholder engagement and public participation are integral parts of the regulatory process, allowing affected communities to voice their concerns and provide input on decisions that may affect them.

3.3 Regional and Local Policies

Regional and local governments are the primary party that shape the climate and environmental policies. They may adopt specific regulations and initiatives tailored to local conditions and priorities, such as regional emissions trading schemes, municipal waste management programs, and urban planning strategies that promote sustainable transportation and energy-efficient buildings. These policies complement national efforts and allow for more targeted actions in response to regional challenges. Regional emissions trading schemes (ETS) are market-based mechanisms designed to reduce greenhouse gas emissions by setting a cap on total emissions and allowing for the trading of emission allowances among participants. These schemes operate at a regional or subnational level, such as within a specific country or group of countries, and aim to incentivize emission reductions while promoting economic efficiency. One prominent example of a regional emissions trading scheme is the European Union Emissions Trading System (EU ETS). Established in 2005, the EU ETS is the largest international carbon market and covers various sectors, including power generation, industry, and aviation. It sets a cap on carbon dioxide emissions and allows participating entities to buy and sell emission allowances. The scheme has undergone several phases and revisions to strengthen its effectiveness and address challenges.

The United States has the California Cap-and-Trade Program implemented in 2013 (Cushing et al. 2018), covering major sectors like electricity generation, industry, and transportation. The program sets a declining cap on emissions, and companies must hold allowances equal to their emissions. Participants can trade allowances through auctions and secondary markets, providing flexibility and encouraging cost-effective emission reductions. Regional emissions trading schemes offer several advantages. They provide economic incentives for emission reductions by allowing companies to trade allowances, enabling them to find the most cost-effective ways to meet their obligations. These schemes also facilitate the transfer of clean technologies and expertise across regions, promoting international collaboration in climate action. However, the design and implementation of regional emissions trading schemes raise ethical considerations. Ensuring a fair distribution of emission allowances and addressing potential disproportionate impacts on vulnerable communities are crucial ethical concerns. It is important to establish mechanisms that prevent market manipulation, ensure transparency in allowance allocation, and mitigate the potential for carbon leakage (shifting emissions from regulated to unregulated areas).

3.4 Corporate Practices and Voluntary Initiatives

Private sector entities, including companies and industries, have a growing responsibility to address climate change and environmental issues. Many businesses adopt sustainability practices, such as reducing greenhouse gas emissions, implementing eco-friendly production processes, and integrating environmental considerations into their supply chains. Voluntary initiatives, such as the Carbon Disclosure Project and the Global Reporting Initiative, encourage companies to disclose their environmental impacts and take steps to mitigate them. These practices contribute to overall sustainability efforts and can influence broader societal norms and expectations. The Carbon Disclosure Project (CDP) (Hassan et al. 2013) is a global non-profit organization that works with companies, cities, states, and regions to measure and disclose their environmental impacts, particularly their greenhouse gas emissions. It provides a platform for organizations to report their carbon emissions, climate-related risks, and opportunities, and sets a framework for transparency and accountability. The CDP operates through a voluntary reporting system, where companies and other entities respond to an annual questionnaire that assesses their environmental performance. The questionnaire covers areas such as emissions data, climate change strategies, governance, and risk management. Participating organizations can disclose their data on a range of environmental metrics, including energy consumption, water usage, and deforestation. The information collected by the CDP serves multiple purposes. It allows organizations to track their progress in reducing emissions, identify areas for improvement, and compare their performance to industry benchmarks. The data also provides investors, policymakers, and the public with valuable insights into companies' environmental performance, enabling them to make informed decisions and evaluate the climate-related risks and opportunities associated with different entities.

From a policy and legal perspective, the disclosure of environmental information through the CDP helps policymakers assess the effectiveness of existing climate policies and identify areas that require further attention. It provides a basis for evidence-based decision-making and can inform the development of new regulations or incentives to drive emission reductions and sustainable practices. The information collected by the CDP can influence investor behavior and financial markets. Investors increasingly consider environmental factors in their decision-making processes and may use CDP data to assess the sustainability and climate resilience of companies. This can lead to changes in investment patterns, capital allocation, and the integration of climate-related risks and opportunities into financial disclosures and provide a platform for collaboration and knowledge sharing, driving progress toward a low-carbon and sustainable future.

4 Ethical and Accountable Challenges for Actionable Science

4.1 Data Quality and Transparency

Issues related to data quality, reliability, and transparency can arise, hindering the ethics of science in real-world scenarios. Lack of data sharing and open access to research findings can impede transparency and accountability. Robust data management practices, data sharing policies, and open science principles are necessary to address these challenges. Inaccurate or unreliable data can lead to flawed analysis and flawed decision-making. Ensuring data quality requires rigorous data collection methods, appropriate calibration and validation procedures, and adherence to quality control protocols. In climate science, data from weather stations and satellites undergo thorough quality checks to ensure accuracy and consistency. The reliability of data refers to its consistency and stability over time, while reproducibility refers to the ability to obtain the same results when an experiment or analysis is repeated. These aspects are essential for establishing the credibility of scientific findings. Transparent documentation of data collection methods, metadata standards, and sharing data in open repositories can facilitate data reliability and reproducibility. It allows other researchers to verify findings, conduct independent analyses, and build upon previous work. Open data initiatives, such as the Global Biodiversity Information Facility (GBIF) and the Open Data Initiative by the World Bank, aim to make data widely accessible to the scientific community and the public. The lack of standardized data sharing policies and practices can pose challenges to data accessibility. Data owners may be hesitant to share their data due to concerns about intellectual property rights, privacy, or competitive advantage. Encouraging the adoption of data sharing policies and establishing data repositories that facilitate data sharing can help overcome these challenges. The Climate Change Initiative of the European Space Agency promotes data sharing among climate scientists and provides open access to satellite data.

4.2 Uncertainty and Risk Communication

Climate and environmental science often deal with complex systems and inherent uncertainties. Communicating scientific findings and uncertainties to policymakers, stakeholders, and the public is a challenge. Ethical communication requires scientists to be transparent about the limitations, assumptions, and uncertainties of their research. This entails acknowledging the complexity of climate and environmental systems and the inherent uncertainties involved in predicting their behavior. Transparent communication helps to avoid the misinterpretation or misrepresentation of research findings, fostering trust in the scientific process. Policymakers, stakeholders, and the public often seek actionable information to inform decision-making. However, it is crucial to strike a balance between providing actionable information and accurately representing uncertainties. Overstating or downplaying uncertainties can lead to misguided policies or misplaced public expectations. Ethical communication should convey the level of certainty or confidence associated with scientific findings, enabling informed decision-making while acknowledging the boundaries of scientific knowledge. Effective communication of scientific findings requires translating complex scientific concepts into clear and accessible language such as avoiding technical jargon and employing effective visualizations or analogies to convey key messages. Ethical communication ensures that scientific information is understandable to a wide range of audiences, including policymakers, stakeholders, and the public. Ethical communication involves engaging with stakeholders throughout the research process including seeking input from stakeholders, incorporating their perspectives, and addressing their concerns. Engaging stakeholders fosters inclusive decision-making processes and enhances the relevance and applicability of scientific findings to real-world challenges. Meanwhile, climate and environmental science often receive significant media attention and scientists have an ethical responsibility to ensure that their research is accurately represented in media coverage. This involves engaging with journalists, providing accurate and contextualized information, and correcting any misinterpretations or misrepresentations that may arise.

5 Guidance on Addressing Ethical Concerns

To address ethical concerns related to transparency and data integrity, researchers should prioritize open data sharing and follow data management best practices, for example, using workflow management tools such as NASA Geoweaver (Sun et al. 2020, 2021, 2022) to document data sources, methodologies, and analytical processes to enhance reproducibility and facilitate collaboration. Real-world examples of initiatives promoting data transparency include the Open Climate Data Initiative and the Global Biodiversity Information Facility (Yesson et al. 2007), which provide open access to climate and biodiversity data, respectively. Ethical considerations demand engaging stakeholders and including their perspectives throughout the research process. This can usually be achieved through participatory approaches, such as involving local communities, indigenous knowledge holders, and non-governmental organizations like the Intergovernmental Panel on Climate Change (IPCC) process, which involves stakeholders in reviewing and synthesizing scientific knowledge for policy making.

Effectively communicating uncertainties is vital to avoid misleading interpretations of scientific findings. Scientists should clearly communicate the limitations, assumptions, and confidence levels associated with their research. Techniques such as probability-based visualizations, scenario-based approaches, and structured expert elicitation can help convey uncertainties. The Climate Futures Toolbox and the International Society for Bayesian Analysis provide resources and guidance on communicating uncertainties in climate science. Modeling and scenario development play a significant role in climate and environmental science. Ethical concerns arise when models and scenarios are used to inform decision-making, as they can have far-reaching implications for society. Researchers should consider ethical dimensions such as distributive justice, intergenerational equity, and fairness in the development and use of models and scenarios. The Shared Socioeconomic Pathways (SSPs) framework (O'Neill et al. 2014) is a high-profile effort to integrate ethical considerations into scenario development. Ethical concerns extend beyond research practices to the conduct of scientists themselves. Researchers should adhere to professional codes of conduct, avoid conflicts of interest, and disclose any financial or institutional affiliations that may influence their work. Ethical leadership is essential for fostering an environment of integrity, trust, and responsible research. Professional societies and organizations like the American Geophysical Union (AGU) provide ethical guidelines and support ethical conduct in climate and environmental science (Marín-Spiotta et al. 2020).

6 Conclusion

This chapter highlights the importance of maintaining ethical standards in scientific research to ensure responsible decision-making. It discusses the current practices, challenges, suggestions, and future outlook on science ethic concerns. The chapter emphasizes the need for transparency, stakeholder engagement, uncertainty communication, ethical modeling, and professional conduct to address ethical challenges in climate and environmental science. Current practices in climate and environmental science involve efforts to promote transparency, data sharing, and open access to research findings. However, challenges arise in ensuring data integrity, addressing conflicts of interest, and effectively communicating uncertainties. To address these challenges, the chapter suggests adopting robust data management practices, promoting stakeholder engagement throughout the research process, and using innovative techniques to communicate uncertainties. The chapter also highlights the importance of ethical leadership and professional conduct among scientists.

In the future we envision a science landscape where ethical considerations are deeply integrated into research practices. This includes enhancing transparency and reproducibility, promoting interdisciplinary collaborations, and addressing societal and distributive justice concerns in modeling and scenario development. By adopting these practices, the scientific community can build trust, engage stakeholders effectively, and ensure that scientific research is used in a responsible and accountable manner to tackle climate and environmental challenges.

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