Outcomes Report:
WHAT ARE SUSTAINABLE CLIMATE RISK MANAGEMENT STRATEGIES?

NSF Cooperative Agreement GEO-1240507

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Overview: The Network for Sustainable Climate Risk Management (SCRiM) addressed the question: *What are sustainable, scientifically sound, technologically feasible, economically efficient, and ethically defensible climate risk management strategies?* SCRiM assembled a transdisciplinary team to support the required integration, tool development, innovation, and education (Figure 1).

SCRiM provided sizeable **broader impacts** such as:

1. Two K-12 workshops that trained 43 teachers from underserved districts in climate change science and strategies for communicating it.
2. Seven summer schools that trained 236 early-career researchers and practitioners in concepts, methods, and tools for analyzing and designing climate risk management strategies (Figure 2).
3. Five summer research experiences providing training and mentoring opportunities for 40 undergraduates and two graduate students representing 28 institutions (Figure 3).
4. Production and distribution of the PBS documentary *Managing Risk in a Changing Climate*.
5. Production and distribution of open-source tools (for example, how to identify robust strategies in the face of uncertainties) and teaching materials (for example, a free textbook on risk analysis), in addition to 165+ publications.
6. Co-support (stipend and/or tuition), mentoring, and training for 9 additional undergraduate researchers, 39 graduate students, and 25 postdoctoral researchers.

Intellectual Merit: Examples of new insights enabled by SCRiM include:

1. Development and application of a new approach to jointly characterize the values and mental models of stakeholders, decision-makers, and analysts. This approach

provided new insights on how to refine decision analyses by, for example, revealing an additional approach to flood risk management in New Orleans (Bessette et al. 2017). In addition to the levee system, participants advocated for community resilience through improvements to transportation, education, and the police force. These insights informed the design of new analyses.

2. Identification of which uncertainties matter most for the design of climate risk management strategies (Lamontagne et al. 2018, Wong and Keller 2017). For an example of managing coastal flood risks, we found that uncertainties surrounding storm surges and the Antarctic ice sheet are more important drivers of variations in projected flood risk than the uncertainties surrounding projections of the Greenland ice sheet dynamics (Figure 4). Climate sensitivity is a key parameter driving how aggressive abatement growth must be to robustly avoid more than two degrees Celsius of global warming (Lamontagne et al. 2019).
3. Quantification of the current state of uncertainties and their possible future developments. For example, the insight that the uncertainty surrounding storm surges strongly drives projected risks motivated refined analyses of how to reduce these uncertainties. We found that future observations can considerably reduce this uncertainty within decades (Lee et al. 2017).
4. Quantification of trade-offs between objectives under deep uncertainty. We characterized, for example, the trade-off between abatement costs and the reliability of avoiding more than two degrees Celsius of global warming (Garner et al. 2016). We also analyzed the interactions of deeply uncertain societal and hydrologic factors to understand the robustness of infrastructure and the rules by which it is operated (Quinn et al. 2018).

SCRiM provided **transformative impacts** for students, researchers, and the broader community. A key example is the careful and sustained integration of diverse disciplines such as engineering, statistics, applied ethics, social sciences, Earth sciences, and decision sciences (Figure 5). This approach helped to train a new generation of researchers and spawn new activities such as the NOAA Mid-Atlantic RISA (MARISA), the Penn State Initiative for Resilient Communities (PSIRC), and the Chesapeake Bay Coastal Climate Extension Program, all targeted at addressing local decision-support needs.

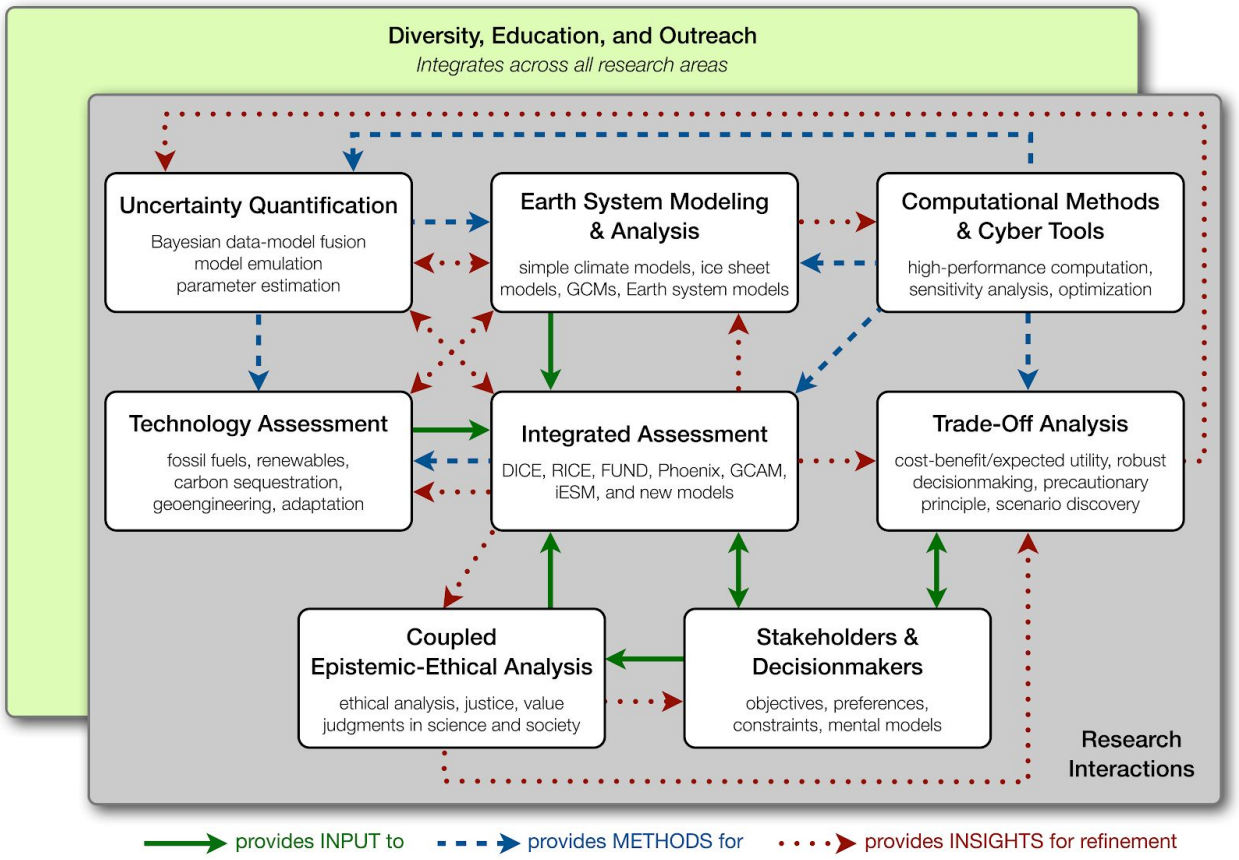

Figure 1: Graphical representation of the SCRiM network design. Figure by Klaus Keller and Robert Nicholas (Penn State University). Distributed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license.

Figure 2: Participants and instructors from the Seventh Annual Summer School on Sustainable Climate Risk Management, held at Penn State University in summer 2019. Photo by Francisco Tutella (Penn State University). Distributed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license.

Figure 3: Participants from SCRiM's 2014-2019 Summer Scholars program. Photos by Katerina Kostadinova (Penn State University), Alex Baruch (Virginia Institute of Marine Sciences), and Tavhata Boyer (Penn State University). Distributed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license.

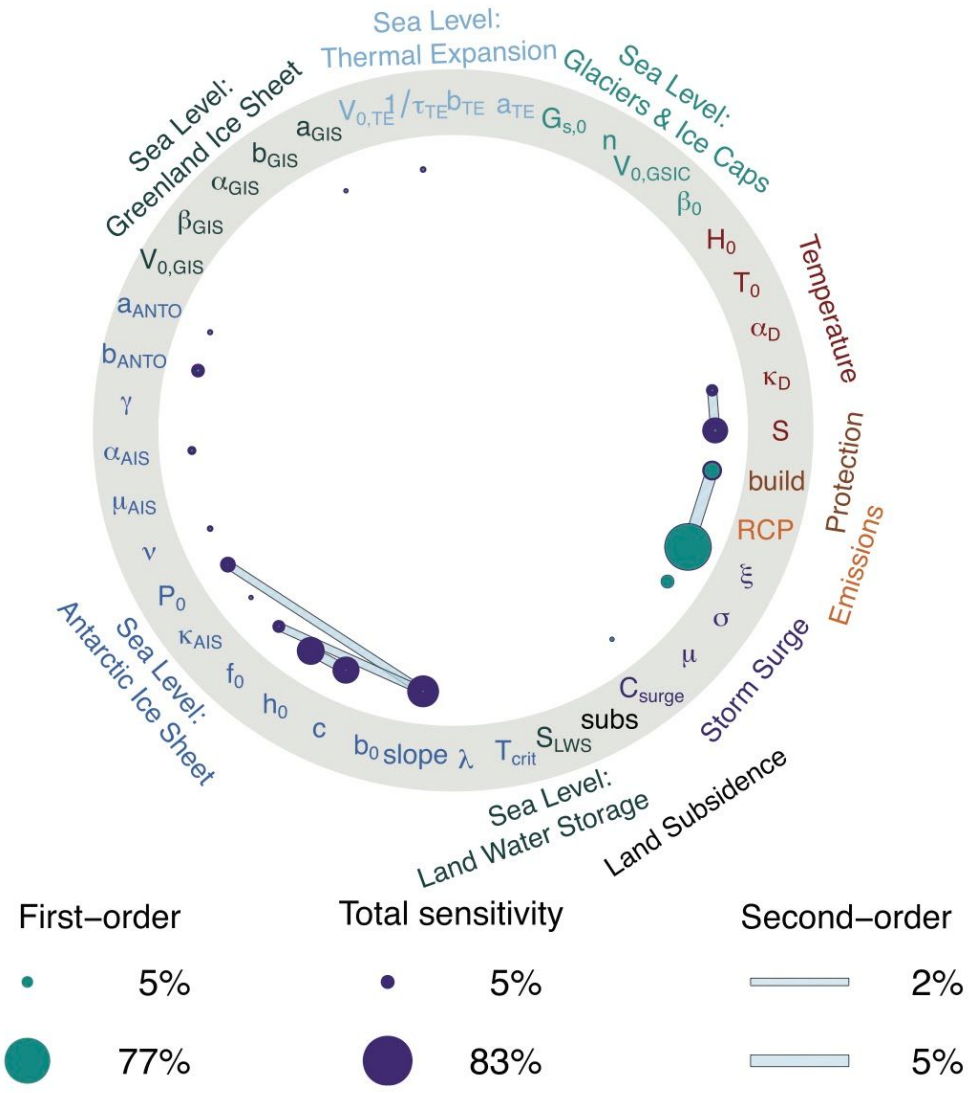

Figure 4: Quantification of the relative importance of key considered uncertainties for projected flood risk over the next few decades. The size of the filled purple nodes represents the total effect of the parameter. The width of the connecting lines represents the importance of parameter interactions. The figure and publication from which it is drawn (Wong and Keller 2017) are distributed under the Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International (CC BY-NC-ND 4.0) license.

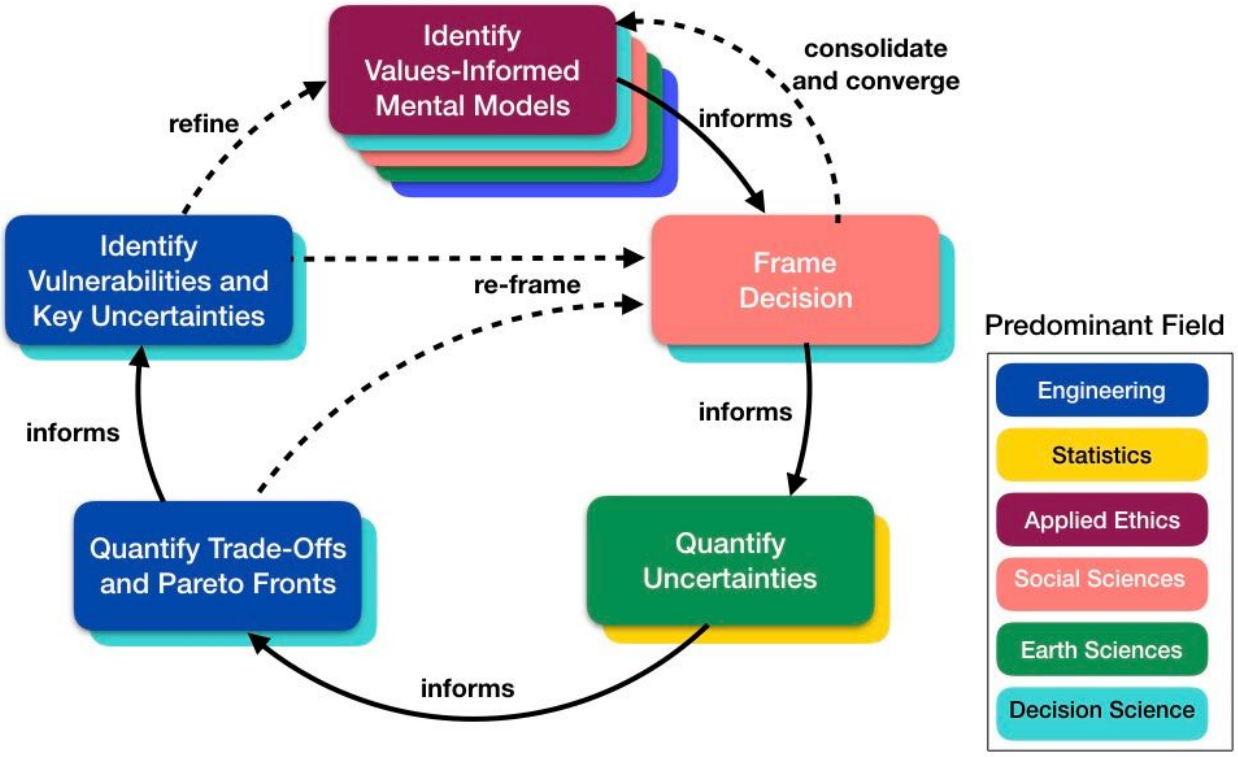

Figure 5: Workflow showcasing the integration of key relevant disciplines. Figure by Klaus Keller (Penn State University). Distributed under the Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) license.

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