Enhancing Regional Climate Accuracy Through Earth Balance and Regional Climate Models

Framing the Unknown: Climate Model Uncertainty, Public Trust, and the Ethics of Communication

A Thesis Prospectus

In STS 4500

Presented to

The Faculty of the

School of Engineering and Applied Science

University of Virginia

Bachelor of Science in Computer Science

By

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Dec 5, 2024

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

In today’s world, it is routine to check the daily news and see a new weather phenomenon occurring in the United States. For North Tampa, Hurricane Milton and Ian have wreaked havoc in the past two years bringing about significant worries to residents of Florida. Questions arise: 'Will I have enough time to evacuate?' or 'If I stay, will I be able to afford essential supplies such as food, water, and power for several weeks? Hurricane Milton, which made landfall as a Category 3 after initially being projected as a Category 5, incapacitated cell towers, uprooted enormous oak trees, endangered civilians, and tore fences as if they were made of paper. Water levels rose to the windows of cars and in the end, the hurricane unfortunately claimed 24 lives (Lund, 2024). The effects of Category 3 Hurricane Milton were devastating, yet remarkably, they could have been even more catastrophic. Milton may have never developed into a hurricane if not for the “record-high ocean temperature across the tropical Atlantics” and the “moisture stockpiled in our warming atmosphere”, both linked to global warming, which created ideal conditions for Milton’s explosive growth (Koren, 2024).

For the climate models that predict and assess catastrophic events like Milton, they are fairly accurate in capturing broad trends of global temperatures and precipitation but lack accuracy on the regional scale. Uncertainties will arise from feedback mechanisms like cloud coverage or the melting rates of ice which make it harder to make precise predictions in specific locations or for predictions that are on shorter timescales. Climate models have a significant impact on public policy and the public's opinions on global warming. First, these models can lead to overestimation or underestimation of the impacts of global warming which lead to poorly targeted policies for global warming. Most importantly, inaccuracies can erode the public’s trust in climate science if the worst-case scenarios fail to happen or the effects of climate change are not as significant as predicted. This can lead to skepticism from the public and reduce public support for climate action which makes it exponentially harder to implement necessary measures to combat climate change. With the significance of creating accurate climate models and effectively conveying the shortcomings of said models, the perception of climate change from the public is paramount. With their support, politicians will put more emphasis on legislation to mitigate climate change and the weather phenomenon that accompanies it. This central motion is expressed by the question, “What are the primary sources of uncertainty in long-term climate predictions, and how do climate scientists, policymakers, and the media navigate and communicate these uncertainties to shape public perception and climate policy?”. Related to the uncertainties that greatly impact public perception and climate policy, my technical project involves creating an Earth Balance Model (EBM) coupled with a Regional Climate Model (RCM) ultimately improving the accuracy of climate projections for specific regions, namely North Tampa.

Technical Project

Climate models play a crucial role in understanding the complex interplay of atmospheric, oceanic, and land-based processes that drive weather and long-term climate patterns. The significance of reliable climate models extends beyond academic interest; they are foundational for making informed public policies, planning infrastructure, and mobilizing communities to adapt to or mitigate the impacts of climate change. Concerning these models, it was expressed earlier that feedback mechanisms like cloud coverage make it harder to make predictions for precise predictions in specific locations. My technical project will combine a rudimentary Earth Balance Model (EMB) alongside a Regional Climate Model (RCM) to address these uncertainties by integrating global climate influences with localized details, allowing for more accurate and region-specific climate projections (Ruosteenoja, 2024).

EBMs are simplified models that represent the balance between incoming solar radiation and outgoing thermal radiation. The primary goal of EBMs is to understand how the flow of energy throughout the planet influences Earth’s average temperature. Despite their simplicity, EBMs are valuable for examining fundamental climate mechanisms in their ability to provide insight into the impact of greenhouse gas concentrations on global temperatures (Flath, 2012). While EBMs are excellent for studying broad trends in climate response, they lack the specificity required for local impact assessments or short-term projections. To address the shortcomings of the EBM model, RCMs simulate climate processes at a finer spatial and temporal scale compared to global models. They use data from Global Climate Models (GCMs) to set the overall climate conditions for the region and then consider the specific features of the area, such as its geography, weather patterns, and ocean influences, to make more detailed and accurate climate predictions for that region (USDA Climate Hubs, 2024). Due to this, RCMs are particularly valuable for studying localized impacts of climate change, such as temperature extremes, rainfall distribution, and storm behavior in specific regions. The ability of RCMs to capture fine-scale variations makes them indispensable for understanding the effects of climate change on regional scales, however, the accuracy of RCMs depends on the quality of input data and parameterizations, leading to uncertainties that can affect model outputs (Tapiador, 2019).

Regarding the quality of input data in developing my Earth Balance Model (EBM) and Regional Climate Model (RCM), there exist several key features that will be integral to the function of the models. First, I will focus on incorporating accurate inputs on the global scale, comprising of statistics of atmospheric composition, solar radiation, and greenhouse gas concentrations for the EBM. For the highresolution regional data of the RCM, I will be considering local features such as topography, land use, and sea surface temperatures, all of which describe the regional climate dynamics. Specific decisions I will make involve selecting the appropriate global climate models (GCMs) to initialize the RCM simulations. This is paramount as selecting the overall climate conditions for the region prepares the model to account for key regional variables like terrain and ocean currents to ultimately give predictions of temperature, rainfall, and extreme weather patterns. Furthermore, I will put extra emphasis on calibrating the model, and validating it with observational data will be an essential step in refining the model's predictive ability, ensuring that the model outputs align with real-world observations.

With all these input features in mind, I will tailor my model towards Northern Florida, a hotspot for extreme weather events. In regions like this that are more susceptible to the catastrophic hurricanes that rising temperatures spur on, the importance of public perception and policies to mitigate climate change matter significantly more than other regions in the country and world. The model can be used in numerous beneficial ways, particularly in informing policy decisions, disaster preparedness, and community resilience strategies. In the instance of Florida, the model can offer local authorities highly localized climate projections, helping them design specific infrastructure upgrades and craft disaster preparation plans. To continue with this point, it can even help to guide emergency response systems. In cases of flooding, the model can model the areas that are at the most risk. Emergency response systems can be centered around the areas that are at the most risk, and areas that are predicted to be in lifethreatening risk can be evacuated before the natural disaster hits.

STS Project

Climate models are inherently uncertain. Building on the technical aspects of refining climate models, my STS project will delve into how said uncertainty can be communicated to policymakers and the public to drive effective climate action. Knowing that uncertainty is inherent in climate models, where do they stem from? Parametric uncertainties like those in population growth, productivity growth, and climate sensitivity were the significant influencers of model variance (Gillingham, 2016). The other significant component, the structural composition of different models had significantly less of a bearing on the variance and uncertainty in climate models. This is crucial as this knowledge enables more targeted efforts to developing policy frameworks centered around addressing these parametric uncertainties. There now exists research that suggests a "satisfying approach" that advocates for achieving acceptable outcomes given the uncertainty in climate models instead of searching for the "perfect solution" (Athanasoglou, 2016). It is unrealistic to obtain a perfectly optimized solution to the climate solution problem, so through the "satisfying approach", policymakers can focus on achievable goals that mitigate environmental impacts in more flexible, adaptive strategies, where incremental progress is prioritized.

No matter how accurate climate models may be, the results and efficacy of a climate model will never be realized if the context and conclusions of a climate model are not clearly and directly communicated to the general public. The aspect of communicating the results of climate models is substantially more significant than the actual climate model itself. It is the basis of the trust that the public has in the climate models and the level of importance that they associate with the looming problem of climate change. Gaining public trust is exceptionally challenging, as accurate climate predictions often go unrecognized, while incorrect predictions rapidly erode confidence in climate models. Wynne demonstrates the importance of communication through the case of the Cumbrian sheep farmers, who lost trust in scientists after being given inconsistent advice about radioactive contamination following the Chernobyl disaster. The scientists dismissed the farmers' local knowledge, acted in an arrogant and disconnect manner to the farmers, and conveyed inconsistencies in their information to the farmers (Wynne, 1992). This emphasizes that public confidence relies not only on scientific accuracy but also on clear and effective communication that respects and acknowledges local perspectives—essential elements for building trust in climate models and addressing the challenges of climate change. In addition to communication failures, public distrust in scientists often arises from broader systemic and historical issues. Perceived conflicts of interest, such as ties to industries with vested agendas, can lead people to question the impartiality of scientific findings. A lack of transparency in decision-making processes may further erode trust, as it can give the impression that scientists are prioritizing institutional interests over public well-being. Moreover, social and cultural factors, including the perception that scientific institutions dismiss local knowledge or fail to align with community values, amplify these concerns. Addressing these interrelated dynamics is crucial for fostering trust in climate science. Building on this notion, Paul Edwards expresses the idea of clear and compelling communication through the use of eye-popping metrics that serve as "stabilized facts" or "anchors" to help facilitate understanding (Edwards, 2013). Accessible visualizations, simplified summaries, and clear framing will help to transform ambiguous scientific knowledge into insights that can be understood and acted upon.

Speaking of public trust in climate models, studies demonstrate that past climate models have generally been accurate in projecting global temperature trends, especially when adjusting for differences in emissions assumptions (Hausfather 2020). Thereby, this should bolster confidence in the predictive power of current models and reduce skepticism about the reliability of climate models. This evidence can also help bolster public and policymaker confidence in the use of models for decision-making, particularly in framing climate action policies with clear, scientifically grounded predictions. The combination of both "anchored" communication and climate models that have been extremely accurate creates a driving force for the public and policymakers to take the necessary steps toward mitigating future climate impacts. Finally, when analyzing the effects of catastrophic weather events that the climate models analyze, the negative effects of hurricanes can worsen through infrastructure failure. In regions prone to extreme weather like Northern Florida, aging, interdependent systems like water and energy can be severely impacted by climate change, amplifying the cascading effects of extreme events such as hurricanes or flooding (Putman, 2013). By using climate model predictions to inform urban planning and infrastructure upgrades, we can ensure long-term sustainability of America's precious cities.

To address my research question, I will conduct content analysis of past hurricanes and other extraordinary weather events will be invaluable. By analyzing historical natural disaster data, I can identify patterns in how extreme weather events, such as hurricanes, have been predicted in past climate models, and assess the discrepancies between predicted and actual outcomes. This will allow me to pinpoint specific sources of uncertainty, such as the difficulty in predicting the frequency, intensity, and regional impacts of such events. Furthermore, meta-reviews of existing climate studies will provide a broader understanding of the various uncertainties inherent in longterm climate models. Specifically, reviewing how climate scientists, policymakers, and the media have responded to and communicated these uncertainties in different manners will shed light on how language, framing, and visualizations impact public understanding and policy formation. The way in which these uncertainties are interpreted by groups in diverse ways remains a mystery in the context of my research question and the ways in which these perceptions influence the effectiveness of climate policy implementation will come to light.

Conclusion

All in all, the increasing severity of weather phenomena highlights the need for accurate climate models. While current models capture broad global trends effectively, they often fall short in precision at regional. Integrating models, such as combining Earth Balance Models with Regional Climate Models, can enhance regional climate projections' accuracy. This combination of models can provide more precise predictions, informing better policy decisions and resilience strategies, particularly in regions highly susceptible to extreme weather like Northern Florida. In terms of models' predictions, inaccurate or poorly communicated model predictions can foster skepticism and reduce public support for climate action. Therefore, transparent communication of the uncertainties in climate models by scientists, policymakers, and the media is essential for maintaining trust and driving collective action.

With all this in mind, why should you care? Imagine the childhood beach you adored as a child. Dipping your toes in the cold water, swimming out as far as you can until your arms hurt, and leaving the beach with a sunburn and a dripping ice cream cone in your hand. Those memories that we cherished as kids will cease to exist for future generations. Rising sea levels are projected to increase by six feet as the worst possible estimate if nothing is done about the current level of greenhouse emissions. The beach would be at risk from constant flooding, and increased storm surge impacts, and a large part of the beach would be underwater by the end of the century. Over time, childhood homes and entire cities could be lost, transformed into reminders of inaction and missed opportunities to safeguard our future. The decisions that we have made as humans have been building for centuries and the implications will be dire, whenever they may come. Developing accurate climate models and communicating their findings effectively to capture public attention is essential for preserving the cherished childhood experiences of future generations.

Works Cited

Athanasoglou, Stergios, et al. Simple Framework for Climate-Change Policy Under Model Uncertainty. Fondazione Eni Enrico Mattei (FEEM), 2016.

"Basics of Global Climate Models." *Basics of Global Climate Models | USDA Climate Hubs*, www.climatehubs.usda.gov/hubs/northwest/topic/basics-global-climate-models. Accessed 5 Dec. 2024.

Edwards, Paul N. A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming.

MIT Press, 2013.

Daniel Flath, Energy Balance Models, archive.dimacs.rutgers.edu/MPE/Energy/DIMACS-EBM.pdf. Accessed 10 Nov. 2024.

Evaluating the Performance of Past Climate Model Projections - Hausfather - 2020 - Geophysical Research Letters - Wiley Online Library, agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2019GL085378. Accessed 30 Oct. 2024.

Francisco J. Tapiador a, et al. "Regional Climate Models: 30 Years of Dynamical Downscaling." Atmospheric Research, Elsevier, 21 Nov. 2019, www.sciencedirect.com/science/article/pii/S0169809519308403.

Gillingham, Kenneth, et al. Modeling Uncertainty in Climate Change: A Multi-Model Comparison. Fondazione Eni Enrico Mattei (FEEM), 2016. JSTOR, http://www.jstor.org/stable/resrep15084. Accessed 29 Oct. 2024.

Koren, Marina. "Hurricane Milton Made a Terrible Prediction Come True." The Atlantic, Atlantic Media Company, 10 Oct. 2024, www.theatlantic.com/science/archive/2024/10/hurricane-milton-seasonpredictions-climate-change/680205/.

Lund, Jeb. "The Story of the Hurricanes." The Nation, 17 Oct. 2024, www.thenation.com/article/society/the-story-of-the-hurricanes/.

Putman, Scott D., and Ebook Central Sustainability eBook Subscription. Climate Change, Infrastructure, and Urban Systems: Vulnerabilities and Impacts. Nova Science Publishers, 2013.

Ruosteenoja, Kimmo, and Jouni Räisänen. “Incorporation of RCM-Simulated Spatial Details into Climate Change Projections Derived from Global Climate Models - Climate Dynamics.” *SpringerLink*, Springer Berlin Heidelberg, 20 June 2024, link.springer.com/article/10.1007/s00382-024-07258-3.

Wynne, B. (1992). Misunderstood misunderstanding: social identities and public uptake of science. Public Understanding of Science, 1(3), 281-304. https://doi.org/10.1088/0963-6625/1/3/004