Judges' Commentary: Climate Change and Regional Instability

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Introduction

This year's environmental science problem challenged students to explore the impact of climate change on fragile states where the government is not able to provide the basic essentials to its people. Teams sought to develop a model to determine a country's fragility while simultaneously measuring the impact of climate change.

The effects of climate change, to include increased droughts, shrinking glaciers, changing animal and plant ranges, and sea level rise, are already being realized and vary from region to region. The Intergovernmental Panel on Climate Change suggests that the net damage costs of climate change are likely to be significant. Many of these effects will alter the way humans live, and may have the potential to cause the weakening and breakdown of social and governmental structures. Consequently, destabilized governments could result in fragile states.

A fragile state is one where the state government is not able to, or chooses not to, provide the basic essentials to its people. For the purpose of this problem "state" refers to a sovereign state or country. Being a fragile state increases the vulnerability of a country's population to the impact of such climate shocks as natural disasters, decreasing arable land, unpredictable weather, and increasing temperatures. Non-sustainable environmental practices, migration, and resource shortages, which are common in developing states, may further aggravate states with weak governance (Schwartz and Randall, 2003; Theisen, Gleditsch, and Buhaug, 2013). Arguably, drought in both Syria and Yemen further exacerbated already fragile states. Environmental stress alone does not necessarily trigger violent conflict, but evidence suggests that it enables violent conflict when it combines with weak governance and social fragmentation. This confluence can enhance a spiral

The UMAP Journal 39 (2) (2018) 187–196

of violence, typically along latent ethnic and political divisions [Krakowka et al. 2012].

Problem Summary

Teams were asked the following basic tasks:

Task 1: Develop a model that determines a country's fragility and simultaneously measures the impact of climate change. The model should identify when a state is fragile, vulnerable, or stable. It should also identify how climate change increases fragility through direct means or indirectly as it influences other factors and indicators.

Task 2: Select one of the top 10 most fragile states as determined by the Fragile State Index (`http://fundforpeace.org/fsi/data/`) and determine how climate change may have increased fragility of that country. Use your developed model to show in what way(s) the state may be less fragile without these effects.

Task 3: Use your model on another state not in the top 10 list to measure its fragility, and see in what way and when climate change may push it to become more fragile. Identify any definitive indicators. How do you define a tipping point and predict when a country may reach it?

Task 4: Use your model to show which state driven interventions could mitigate the risk of climate change and prevent a country from becoming a fragile state. Explain the effect of human intervention and predict the total cost of intervention for this country.

Task 5: Will your model work on smaller "states" (such as cities) or larger "states" (such as continents)? If not, how would you modify your model?

Judges' Criteria

The general framework used to evaluate submissions for the environmental science problem is described here. The judges who utilized this framework included representatives from a diverse set of fields, including sustainability, biology, geography, applied mathematics, statistics, and engineering. Their main objective in the problem judging was to find and evaluate modeling that included good science and led to measurable and viable solutions. The judges were looking for papers that clearly communicated each of the following elements:

- Does the team understand the complexity of the problem?
- Does the team develop one meaningful model to measure a country's fragility while incorporating the impact of climate change and use that same base model throughout their paper?

- Does the team apply and explain the results of their model for a country within the top 10 most fragile states, a country outside of the top 10, and include a discussion on the application of the model to both smaller and larger "states"?
- Does the team present a relevant and feasible set of intervention strategies tailored specifically to the region?
- Does the team integrate the required tasks into a story in order to address the overall issue linking a state's stability to their vulnerability to climate change?

Recognition of the Outstanding Papers

Due to the nature of the environmental problem, the competing teams used varying modeling techniques focusing on different indicators for climate change and fragility. Teams also selected diverse countries for their analyses. As a result, the submissions provided great innovations and excitement for the judging panel.

Each of the seven Outstanding papers used different methodologies while addressing the problem associated with the vulnerabilities of fragile states and the impact of climate change. These Outstanding papers were generally well-written and provided clear explanations of their modeling procedures. Some demonstrated unique and innovative approaches distinguishing themselves from other papers. Others were noteworthy for either their thoroughness of their modeling or the significance of their results. Some provided well thought-out, implementable intervention strategies, perfectly tailored to the chosen country. We would like to congratulate the seven Outstanding papers from Problem E:

- Nanjing University, Nanjing, Jiangsu, China: "A Probabilistic Model of the Relationship between Countries and Climate Change"
- Nanjing University of Information Science and Technology, Nanjing, Jiangsu, China: "Climate Counts! Less Fragility and Better Countries"
- Shanghai Jiao Tong University, Shanghai, China: "SPEC—A Climate-Based Fragility Model"
- Shenzhen University, Shenzhen, Guangdong, China: "Climate Change's Influence on Regional Instability"
- Skidmore College, Saratoga Springs, New York, USA (INFORMS Award and COMAP Scholarship Award): "Climate Changes Influence on Regional Instability"
- University of Electronic Science and Technology of China, Chengdu, Sichuan, China: "An Evaluation Model of State Fragility Related to Climate Change Based on the PSR Model and Entropy Weight Method"

- Xi'an Jiaotong University, X'ian, Shaanxi, China (Rachel Carson Award and COMAP Scholarship Award): "How Will Climate Change Affect Fragility?"

Discussion of the Judges' Criteria

To understand the components that the judges used in determining the best papers, we offer commentary on the critical components of the environmental science problem and highlight the innovation seen in this year's Outstanding submissions.

- **Does the team understand the complexity of the problem?** The two award-winning Outstanding teams demonstrated a strong understanding of the complexity of the problem. Before tackling the model, the team from Skidmore College had a nice conversation about fragility and its impacts. They determined qualitative definitions for stable, vulnerable, and fragile states, which then, based on data analysis, were translated into quantitative tipping points that were incorporated into the model to determine and analyze a country's fragility state. Additionally, the Skidmore team detailed the metrics that contributed to a state's fragility and categorized them into three subgroups (climate change, economic, and political/demographic) before incorporating them into their model. The discussion and background provided by the team gave the judges confidence in their understanding of the motivations of this problem and the grounding of their model in the realities and complexities that exist today.

  The team from Xi'an Jiaotong University began their paper with a precise literature review targeted at the difference between resilient and fragile states. They underscored the successes of previous research from three different sources and then discussed the limitations of the work for solving the problem at hand. After identifying two weaknesses, the team set out to address those in their work, to determine a more complete and useful model of fragility based on additional factors related to climate change.

- **Does the team develop one meaningful model to measure a country's fragility while incorporating the impact of climate change and use that same base model throughout their paper?** There were many methods used by teams to create a metric for determining a country's fragility. The judges determined that a well-researched and developed model should include an explanation of the reasoning behind the chosen approach as well as the assumptions used in developing the model. Outstanding teams motivated their model with background research, such as we saw above, before presenting their techniques.

Judges were impressed by the variety of ways that teams chose to create their metric. The foundation of the metric was the analysis of which factors to include. The judges read papers from teams that developed completely original models, while other teams leveraged and improved upon models available from literature. The best teams created a unique model and then conducted verification by testing it against a known metric identified through their research. Regardless, the expectation remained that teams cite work that is not their own.

We want to caution teams from over-modeling. A verified, simpler model may be better than incorporating an additional advanced method in order to demonstrate increased mathematical knowledge. Teams that developed a strongly-researched, well-explained model, with details of its strengths and weaknesses applied throughout the paper, were judged highly, such as the Outstanding teams from Shenzhen University and Nanjing University of Information Science.

The team from Shenzhen University used a pressure-state-response model with weights determined through the Analytic Hierarchy Process and entropy weight methods. These were methods that we saw in many papers; but what we appreciated the most in this paper was the specification of direct and indirect impacts of climate change on fragility. This discussion was accompanied by a description of how they were incorporated differently into the model; this feature made this model stand out from others. The time that this team spent in identifying good measures, describing why they should be included, and then graphically depicting how they influence the model, was appreciated by judges.

Like the team from Shenzhen, the team from Nanjing University of Information Science did not necessarily use a novel approach: They used standard methods to develop the model, but the description of their procedure was the best that we had read. The team used the entropy weight method and the coefficient variation method, as well as a fuzzy cluster analysis, to group countries into the four categories of impregnable, stable, vulnerable, and fragile. They were clever with determining their indicators, and their discussion of techniques was solid. Additionally, they distinguished themselves by starting with a model without climate change that predicted fragility and then added climate change indicators to see the difference in the power of prediction of the new model.

- **Does the team apply and explain the results of their model for a country within top 10 most fragile states, a country outside of top 10, and include a discussion on the application of the model to both smaller and larger "states"?** Here judges were simply looking for teams to address the requirements specified in tasks 2, 3, and 5. Since time is limited, all initial efforts must be dedicated to answering all the questions that are asked in the problem statement. Outstanding teams always ad-

dress all aspects as required and then often go beyond for a particular aspect.

Validation and sensitivity analysis often set a great paper apart from just a good report. Validation is an important part of the modeling process, since it can instill confidence in the results or help identify weakness in the model. Several papers presented a range of models from simple to complex and used a validation approach to justify the selection of one of those choices, considering the trade-offs. Many of the strong papers, at a minimum, conducted a validation based on another commonly-accepted published measure, in order to compare predictions. Additionally, sensitivity analysis can be done in a variety of ways, so judges were looking closely at the rationale behind each team's approach. Some teams revisited simplifying assumptions, while others assessed the relative impacts of different types of improvements. There is no one way; but teams that attempted a sensitivity analysis in order to determine the robustness, flexibility, or accuracy of their model demonstrated to the judges a higher level of knowledge concerning the impact and usefulness of their model.

All of the Outstanding teams provided detailed answers for the three tasks associated with this criterion. What distinguished them was the validation of their results. For example, all seven of the Outstanding teams included the comparative analysis of their chosen top-10 country by discussing the results of their model as compared to at least one other known model. Additionally, the team from the University of Electronic Science and Technology of China included a nice reflection on the aspects that came out differently whenever they conducted validation. Their detail on the types of countries that were anomalies in their model was excellent and drove them to a nice discussion and reasoning behind their weaknesses and then the weaknesses of other known metrics.

- **Does the team present a relevant and feasible set of intervention strategies tailored specifically to the region?** Judges appreciated the discussion that strong teams presented on the variety of considered intervention strategies. An explanation of possible strategies, and then justification of analysis of strengths and weaknesses of those implemented, was preferred. Teams that truly extended themselves and did not confine themselves to standard or already-implemented strategies were praised by the judges. We saw such innovative intervention plans that were truly tailored to a specific country or region in crisis. Once the intervention plan was determined, implemented, and analyzed for effectiveness, using the team's model, and the plan's cost determined, the intent was to analyze long-term impacts on a state's fragility. Judges understood the need to implement forecasting methodologies but were discouraged when they saw teams adopt completely new models in order to determine the effect of their intervention strategies.

The presentation of the intervention strategies for Sudan from the team from Nanjing University impressed judges. The team presented the analysis within a table to explain the proposed state-driven interventions that would help Sudan increase its resilience to climate change. Every indicator within their model had a reasonable associated intervention strategy, an analysis of the impact on fragility, and an associated cost.

The presentation of the team from Skidmore College also impressed the judges. After the model description, the team presented country analysis for one country on the top 10 list and two countries not on the top 10 list. In the analysis for each country, the team presented intervention strategies that could mitigate the risk of climate change, while explaining the effect of the human intervention on the future state of the country, together with the overall associated cost. This additional analysis for three different types of nations led to a set of diverse intervention options, all appropriately targeted to the country at need.

- **Does the team integrate the required tasks into a story in order to address the overall issue linking a state's stability to their vulnerability to climate change?**

  Every year, the judges seek to highlight submissions that offer a balance of sound mathematics with well-written justifications. The strongest submissions have a clear organizational structure, with equations coupled with explanations and, where appropriate, graphics to help convey complicated ideas, along with appropriate citations completed to given appropriate credit to past problem solvers.

  This year's Outstanding papers included clearly presented ideas that are introduced in a logical sequence, with transitions between topics to link the document together, but even more critical, to ensure that each new result complements the overall story of climate change and its influence on the instability of nations.

  Teams from both Xi'an Jiaotong University and Shanghai Jiao Tong University had very readable submissions. The team from Xi'an Jiaotong University began in their summary by outlining exactly what they were going to present, and then throughout the paper they contributed detailed explanations that supported their summary, always tying the need for this analysis back to climate change exacerbating fragility. Judges commented that the paper from Shanghai Jiao Tong University read like a well-scripted story that was so easy to read and kept you engaged, wanting to know more as they linked the effects of climate change to the fragility of certain nations.

Recommendations to Future Participants

The judges recommend focusing on three areas for those attempting the environmental problem during next year's competition:

- First, make a plan for the weekend and conduct the initial research.
- Next, solve the problem and all of the subtasks that were outlined in the problem statement.
- Last, ensure that you present your solutions and your recommendations thoughtfully with explanations and interpretations.

- **Make a Plan** We encourage teams to have a plan for the 96 hours and then adjust as needed in order to ensure a completed solution and submission. Every year, there are submissions that do a tremendous job on one aspect of the problem but then are unable to complete their solution, obviously due to a lack of time or lack of coordination of the plan. To coordinate your plan, leverage the strengths of individual team members. The more that your team can synchronize the efforts of its members and integrate the writing into a seamless paper, the stronger your final submission will be. Incorporate time into the plan for the best writer to edit and ensure smooth transitions throughout the document. Lastly, ensure that research is the first aspect of your plan. It is important to do the research up front and understand the context of the complex interdisciplinary problem. The judges do not expect teams to be experts in all of the aspects of a particular problem, but we do expect you to read about the environmental situation so that you ensure you know what you are actually modeling.

- **Solve the Problem** Since time is limited, all initial efforts must be dedicated to answering all the questions that are asked in the problem statement. Outstanding teams always address all aspects as required and then often go beyond for a particular aspect. Additionally, remember that a simple model can be just as effective as a complex one! As noted in the previous discussion, a simple model that is nicely researched, explained, and implemented impresses the judges when coupled with excellent contextual real-world interpretation of the environmental crisis that we are trying to solve.

- **Interpret and Present** Remember that the motivation for this competition is the real-world environmental problem. Therefore, the model itself is not the solution. Outstanding teams always use the models to produce interpretable applicable results as well as a recommendation for a solution. Throughout your process, explain what you are doing as well as your reasoning. The judges desire to read the explanations behind what a team is doing and the descriptions of why, not just a list of equations and numbers without words. If you are using information

from other sources in your model or analysis, ensure that you use strong references for that information and then cite them accordingly. This last aspect is critical: Please ensure you give appropriate credit to the sources used throughout your research.

Conclusion

This problem presented challenges to teams in the form of understanding the complications of both climate change and stability of a nation, as well as the linkage between the two. Both needed to be incorporated into a model to help analyze a country's fragility.

We congratulate members of the competing teams for their excellent work and dedication to interdisciplinary modeling and problem solving. Overall, the judges were truly impressed by the ability of so many to combine great modeling, well-researched science, and effective written communication skills in order to address this critical issue.

References

Fund for Peace. 2018. 2018 Fragile States Index. http://fundforpeace.org/fsi/ .

Krakowka, Amy Richmond, Natalie Heimel, and Francis A. Galgano. 2012. Modeling environmental security in sub-Saharan Africa. *Geographical Bulletin* 53 (1): 21–38. http://gammathetaupsilon.org/the-geographical-bulletin/2010s/volume53-1/article2.pdf .

Schwartz, P., and D. Randall. 2003. An abrupt climate change scenario and its implications for United States national security. October 2003. http://eesc.columbia.edu/courses/v1003/readings/Pentagon.pdf .

Theisen, Ole Magnus, Nils Petter Gleditsch, and Halvard Buhaug. 2013. Is climate change a driver of armed conflict? *Climatic Change* 117 (3) (April): 613–625. https://www.hbuhaug.com/wp-content/uploads/2014/02/CC-2013-for-web.pdf .

World Bank Group's (WBG) Fragile, Conflict and Violence Group. 2018. Harmonized list of fragile situations. http://www.worldbank.org/en/topic/fragilityconflictviolence/brief/harmonized-list-of-fragile-situations .

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