Strategic Development of a Cloud-based Data Infrastructure for Hurricane Mobile Apps

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Participating Labs or Entities: NCAR/RAL, UCP/COMET, NCAR/MMM
University Partners: Univ. of Florida (UF), Auburn Univ. (AU), James Cook Univ. (JCU)
Industry Partner: United Services Automobile Association (USAA)
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Total Budget Requested from UCAR PSIOF: $150,000
Co-sponsorship: $13,000 from RAL, $2,337 from UCP/COMET
Supporting documentation: An appendix ("Vigh_Appendix.pdf") is attached with supporting details that include the proposal's market analysis and private sector engagement plan, collaboration plan, proposed project schedule, additional budget information, descriptions of elements and functionality of the content that could be delivered, technical scoping of the costs for cloud-based content and delivery, and references. The appendix also includes a list of additional attachments, including letters of support from our university partners and USAA.

Overview

The RAL Tropical Cyclone Guidance Project (TCGP, http://hurricanes.ral.ucar.edu) provides real-time information on tropical cyclones (TCs) around the world. The site features an overview map and storm-focused pages that provide model guidance plots, links to official products from the U.S. National Hurricane Center (NHC), aircraft observations, and links to satellite and radar loops and other technical resources. TCGP is popular with a diverse set of users and sometimes receives a couple hundred thousand views in a day when major hurricanes threaten the U.S. TCGP also collates model guidance from many sources and provides the associated data streams to the public under the UCAR Terms of Service (which permits non-commercial research uses). On a typical day during the Atlantic hurricane season, 15 - 25 GB of data are downloaded from TCGP, demonstrating the significant demand for such data. In 2017, IBM/The Weather Company inquired whether TCGP's data streams were available for commercial licensing. Historically, NCAR has declined to provide operational real-time data streams due to the effort that is involved in maintaining resources that must be available on a 24/7 basis. However, the recent proliferation of cloud computing services, along with development of

container-based provision of software codes, has significantly lowered the barriers to providing scalable and persistent operational-like data services with high reliability.

The next frontier for hurricane applications is to provide localized hazard information (e.g., for a user-entered street address) and to integrate this information with the user's particular vulnerability and exposure to assess their overall risk due to an impending hurricane. This concept, called the Hurricane Risk Calculator (HRC), was developed through funding from the RAL Opportunity Fund. The conceptual approach aims to apply probabilistic risk assessment methods to translate the resulting risk information into forms that ordinary users can understand. This is being done through the development of a "dashboard" of graphical and textual products that detail information on the projected wind hazard. A key aspect of the HRC is to contextualize the projected wind impacts in light of local design wind speeds to assess the potential structural damage that may result for typical residential construction. The HRC has a goal of providing some initial capability through a web-based dashboard as an experimental resource during the 2019 hurricane season. For more details on the HRC concept, see Vigh et al. (2018).

This proposal seeks strategic funding to develop a cloud-based data and content delivery infrastructure to support hurricane-related mobile apps and data streams for public and private sector uses. Through partnership with our university partners, USAA, and a second private sector partner (to be sought during the project), two demonstration mobile apps focused on providing real-time information about localized hurricane wind hazard will be developed, with substantial guidance and design input from NCAR and COMET. These apps will demonstrate the feasibility and costs associated with cloud-provisioned data streams and content delivery mechanisms, with a major focus on reducing uncertainties related to app usage patterns and for different types of content. Another major goal of the proposed project is to assess the efficacy and feasibility of the HRC approach by conducting retrospective testing using various wind modeling output and comparing to the damage states at hurricane-affected structures. Finally, this project will be used to develop future funded projects to further advance toward the ultimate vision of the Hurricane Risk Calculator, which is to develop fully probabilistic wind modeling and vulnerability curves and effective communication strategies to provide life-saving information directly to users via their mobile devices.

Scientific Merit of the Proposed Work

Time and again, landfalling hurricanes expose issues in the U.S. emergency management system. For example, during Hurricane Irma (2017), evacuation rates in the highly vulnerable Florida Keys only reached 70-80%, despite model projections of a hurricane of potentially record intensity impacting the Keys, mandatory evacuation orders, and intense media coverage of Irma's repeated and vicious landfalls on Caribbean islands as a Category 5 hurricane. FEMA estimated that 10,000 residents remained in the Keys during the storm (out of a normal population of about 78,000). Many of these residents would have faced a high probability of death if Irma had actually hit the Keys as a Category 5 hurricane. Meanwhile, extensive evacuations occurred across many other areas of Florida, including millions of people who were not located in official evacuation zones. This lead to crushing traffic jams that stretched for hundreds of miles.

Research has shown that “ultimately, it’s how individual residents and their households perceive the danger that largely determines whether they evacuate.” (Cara Cuite and Rebecca Morss, Washington Post, September 8, 2017; https://www.washingtonpost.com/outlook/what-to-tell-people-to-get-them-to-evacuate-before-a-hurricane-hits/2017/09/08/09b1efc0-93e0-11e7-8754-d478688d23b4_story.html, accessed November 14, 2017). In the face of uncertainty, which will always be present to some degree, it is vital that hurricane impacts be conveyed to users in forms that are relevant and understandable. Hurricane impacts arise from wind, surge, waves, inland flooding, and other tertiary hazards including tornadoes and landslides. The present proposal focuses on treating wind hazards specifically, although if the proposed development is successful, it will likely lead to funding streams that could support providing localized information for the other hurricane hazards such as storm surge and inland flooding.

The scientific merit of this proposal is that it will demonstrate the provision of localized wind hazard information to users through mobile apps and examine the efficacy of the Hurricane Risk Calculator concept through retrospective testing for past hurricane landfall events. The content delivery platform developed as a result of this project will enable rapid and handy access to potentially life-saving information. Such information, as well as more advanced types of information that would be developed in future follow-on projects, will optimize personal and collective decision making, thus providing risk-informed evacuation guidance and helping user’s mitigate property damage.

Technical Approach

In brief, our technical approach involves the following elements:

- A cloud-based infrastructure will be developed to support the content delivery aspects of this project. This work will include refactoring TCGP to run in the AWS cloud, containerizing and porting the associated data processing and visualization scripts to run in the AWS cloud, and optimizing the server-side infrastructure, visualizations, and Web Map Service-enabled content for delivery to mobile apps. The content delivery platform will be designed to scale based on demand.
- The TCRM-based Kepert-Wang boundary-layer model, recently implemented in the Australia Geoscience Tropical Cyclone Risk Model framework by Dr. James Done and Ming Ge (NCAR/MMM), will be implemented in the cloud-based real-time infrastructure to provide fields for three track scenarios: a) the NHC-predicted track, b) a track that follows the left edge of the cone of uncertainty, and b) a track that follows the right edge of the cone of uncertainty. These time-evolving predicted wind fields will provide three plausible wind scenarios to drive the deterministic version of the HRC.
- A deterministic version of the HRC will be implemented in the cloud-based real-time infrastructure using the three plausible wind scenarios provided by the TCRM-based Kepert-Wang boundary layer model output, as well as the probabilistic information provided by the NHC wind speed probability product. This predicted wind hazard information will be used to assess the user’s risk. This risk will be assessed according to the two key wind speed thresholds used in the user’s local building code: a) the

"acceptable stress design" wind speed, v_{asd} which corresponds to the wind speed with an expected 50-year return period; and b) the "ultimate" design wind speed, $v_{ultimate}$ which corresponds to the wind speed with an expected 700-year return period. v_{asd} corresponds roughly to the wind speed at which structural damage may begin to occur (e.g., non-elastic deformations of the structure, water damage, etc.), while $v_{ultimate}$ corresponds to the wind speed at which the structure's life and safety protection abilities may begin to be compromised. If feasible, additional damage potentials may be estimated by applying a vulnerability curve for the appropriate building type.

- Alerting capabilities will be developed as an optional capability that the user can turn on or off. This will alert each mobile user when new TCs develop in their basin, when such storms are upgraded to hurricanes, and when the potential for damaging winds at the user's selected location increases beyond specific thresholds. (In future funded projects, the alerting capabilities could be greatly expanded and customized to include recommended protective actions, evacuation recommendations, etc.).
- COMET's instructional design expertise will be provided to the Resilient Residence (ResRe) app being developed by our university partners and one or more commercial apps developed by our private sector partners. This input will help to ensure that the app design and functionality provide a good user experience. This will also help to ensure that our partner's apps can utilize our cloud-based data and content delivery service.
- The feasibility of the deterministic HRC approach will be evaluated through an extensive retrospective validation activity. HRC outputs will be run for the locations of a large number of sites that experienced wind impacts in past hurricane events. HRC-predicted damage states will be compared to the actual damage states assessed from on-the-ground damage surveys. The accuracy of the deterministic HRC output will be evaluated to see if it provides accurate and useful information about the damage potential and the ability of the structure to protect life and safety.

Detailed technical scoping and estimates for the costs of provisioning content delivery through the AWS cloud is provided in the Appendix, section F. In brief, the estimated costs of content delivery depend highly on the degree to which Web Map Service (WMS) content is used. WMS-enabled animations may require a large amount of content delivery, whereas simpler static graphics would only require a fraction of the resources to deliver. We estimate that the full cost of data and content delivery to the app for an entire hurricane season for non-intensive content delivery (e.g., without animations) will be less than $0.10 per app user (once scaled up to a large user base on the order of 500,000 users). The cost of content delivery for a fully interactive (zoomable and draggable animated WMS-enabled content) could be as high as $0.45 per app user. We estimate that staff support for ongoing maintenance after the project concludes will be $0.08 per app user per season, based on 500,000 app users. Therefore, any royalties exceeding ~$0.18 per app user per season (for non-intensive apps), or ~$0.53 per app user per season (for intensive WMS-based animations) can be directed into further development and future feature enhancements. These cost estimates are very conservative, so the actual costs of content delivery may be significantly lower.

Anticipated Outcomes

This project will demonstrate the feasibility and costs associated with cloud-provisioned data streams and content delivery mechanisms, substantially reducing the uncertainties related to app usage patterns and for different types of content (e.g., WMS-enabled animations vs. simpler types of content). This knowledge will pave the way toward commercial uses of such data; we anticipate that several private sector partners will be using our cloud-based delivery platform by the 2020 hurricane season. The project will also result in an improved understanding of the efficacy and feasibility of the HRC concept through retrospective testing of the modeled wind fields, critical wind thresholds, and vulnerability curves. This will lead to better understanding on whether the deterministic version of HRC can provide useful information about the actual damage states of hurricane-affected structures.

We also anticipate that the experience and collaborations developed during this project will be leveraged to develop future funded collaborative projects. Such projects are expected to include development of a fully probabilistic modeling framework that accounts for the influences of terrain and the built environment, development of probabilistic vulnerability models for a range of typical structure categories to better assess damage potentials for a range of typical structures and construction styles, projects which integrate this information to provide decision support tools, and finally, social science projects to understand how this information affects decision making and risk perceptions.

Finally, this project will foster significant collaboration between NCAR, UCP, the universities, and the private sector communities by opening up a new model for creating and disseminating real-time data driven by NCAR/UCAR science and enabling a wide new array of commercial uses of such data. This development model could be extended beyond the problem of hurricane hazards to support apps focused on other types of extreme weather-driven hazards, such as hail, tornadoes, wildfires, downslope windstorms, and freshwater flooding.

Budget

This proposal requests $150,000 in funding from the UCAR PSIOF. Additionally, this application leverages $15,337 in monetary co-sponsorship of two Lab/Program Directors. Bill Mahoney (RAL Lab Director) has committed to co-sponsor $13,000 for this proposal (~10.5% of the RAL budget of $124,035). Elizabeth Page (COMET Director) has committed to co-sponsor $2,337 for this proposal (~8.5% of the COMET budget of $27,301). All together, a total of $165,337 will be available to the project, with $124,035 to RAL, $27,301 to COMET, and a $14,000 to a subaward to JCU*. The funds will be spent as follows:

- Salaries $ 75,556
- Benefits $ 41,480
- Purchased services $ 2,433 (cloud-based computing, storage, and data transfer)
- Purchased services $ 595 (printing for 2 posters, abstract fee, Dropbox for Business subscription)
- Domestic travel $ 5,514

- Indirect costs $ 22,024 (15.7% corporate overhead rate)

*The subaward to JCU would significantly help the project, as Dr. Daniel Smith could substantially help with the effort to retrospectively test the deterministic HRC output and other aspects. If a subaward is not possible, then we would like to offer substantial travel support for Dr. Smith to visit NCAR for an extended period.

Narrative Responses to Scoring Questions

Why is this transformational?

Mobile apps have already transformed the business world, causing considerable disruption to established industries and creating entire new sectors. While the number of commercial weather apps has proliferated, their applications in supporting decision support and hazard communication have only scratched the surface of what is possible. This proposal builds on the concept of the Hurricane Risk Calculator, which combines the power of using probabilistic frameworks to model hurricane wind hazard together with the understanding that to offer a useful picture of a user's risk, such information must be convolved with the user's vulnerability and then translated into forms that the users can understand. Once such information is contextualized and put into actionable and understandable forms, it can drive better decision making for evacuation decision support and protective mitigative actions, thereby leading to improved life and safety outcomes and reduced damage losses.

Why is this interdisciplinary?

This project is highly interdisciplinary, spanning the disciplines of atmospheric science, wind and structural engineering, software engineering, cloud infrastructure engineering, user design, and decision support science.

How will this promote collaboration across the greater NCAR, UCP, university and/or private sector community?

The project includes substantial collaborative components and engagement across two NCAR labs (RAL and MMM), a UCP entity (the COMET Program), three universities (University of Florida, James Cook University and University of Auburn), and at least one private sector partner (United Services Automobile Association). Additionally, as the Hurricane Risk Calculator concept develops further, additional collaborations will result with additional university groups, such as groups predicting power outages, etc. This may lead to additional collaborations with private industry, such as the electric utility industry, etc.

What are the expectations that this will lead to future, ongoing funding?

The integrated risk-based approach of this project is likely attract significant interest from the insurance industry, resulting in additional funded follow-on projects. Our private sector partner, USAA, is a major insurance company that is currently negotiating a Task Order Agreement with NCAR, with substantial interest in applying a similar approach to the hail and tornado hazards. We expect that the current project will help to develop future funded projects with USAA.

The Hurricane Risk Calculator concept and associated applications for evacuation decision support should also be of high interest to public agencies and emergency planning entities (e.g., FEMA, Florida Department of Emergency Management, etc.). Additional major funded projects could be envisioned with such partners as the project matures.

Finally, through the development of the three new funding streams (royalties from the commercial partners' demonstration apps, licensing of TCGP's data streams, and licensing of app content delivery), this project will tap into a new types of funding sources that are not dependent on government sources and which have the potential to grow much larger over time. These funding streams will support continued development and expansion of the app's capabilities over time and ultimately contribute to new scientific innovations.

What are your metrics and success criteria to demonstrate achievement?

- **App engagement with test users:** The demo app will be deemed successful if 80% of testers use it at least 25 times during the 2019 demonstration period.
- **App usage in 2020:** It is expected that partner #2's app will experience a broad uptake of at least 500,000 users by the end of the 2020 hurricane season. Success of this criteria may depend on whether the 2020 Atlantic hurricane season is active or inactive.
- **Royalties from our two partner's demonstration apps:** We will consider this metric met if royalties from our partners' apps exceed $200,000 in 2020 ($0.40 per app user, based on 500,000 users). Subtracting the estimated $0.25 per app user costs to support the app (for moderately WMS-rich content), this would leave $0.15 per user (or $75,000) to pour back into development of additional capabilities and content at NCAR.
- **Commercial licensing of the TCGP data stream:** We will consider this metric to be met if at least one significant commercial entity licenses the TCGP data stream, resulting in licensing and/or re-licensing revenue of at least $1000/month.
- **Commercial licensing for the app content delivery:** We will consider this metric to be met if at least two additional mobile apps are developed (beyond our two primary partners' apps), and if such licensing revenue exceeds $50,000 in 2021.

What are your milestones for when these metrics will be achieved?

01 Jul 2019 TCGP's data infrastructure running in the cloud; data available for licensing
01 Aug 2019 At least one significant commercial partner licenses TCGP's data stream
01 Sep 2019 USAA's demo app released to friendly users for real-time testing
01 Feb 2020 2nd commercial partner identified to undertake mobile app development
28 Feb 2020 UCAR PSIOF Period of Performance ends; project continues with partner funding
01 Mar 2020 ResRe app released; cross-promotes other partners' real-time apps
01 May 2020 USAA's app finalized for testing, pushed to consumers in hurricane-prone areas
01 Jun 2020 2nd commercial partner's hurricane app available to public in app stores
31 Oct 2020 2nd commercial partner's hurricane app reaches at least 500,000 downloads
30 Nov 2020 Total royalties or funds to UCAR from our two partners' apps totals $200,000
30 Nov 2021 Total royalties from additional licensing of content exceeds $50,000