Final Submitted Version of the UCAR Proposal "A prototype Earth-gauging system integrating weather and health data to manage meningitis"

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Introduction

The overarching goal of this proposal is to contribute to saving lives and enhancing livelihood in Ghana through integration of health and environmental data, and by using that data in service of health-related decision-making. Specifically, we aim to build and implement a prototype decision-support system that integrates two- to 14-day weather forecasts and epidemiological data to provide actionable information that can be used to contain the spread of meningitis epidemics. By applying a preliminary economic evaluation of this decision support system, we will be able assess the potential benefit of using environmental data to improve public health outcomes, help prioritize continuing investment in meningitis management in Ghana and throughout the Meningitis Belt, and determine the appropriateness of extending the prototype to other diseases, nations, and continents.

This effort is a small piece of an overall Google.org effort to develop an *Earth-gauging System* that will integrate environmental, health and development data into products that stakeholders and researchers can use to monitor variables, analyze trends and identify relationships among different variables. The *Earth-gauging System* will support the prediction of emerging threats, and provide the basis for an robust early-warning system that will improve health, food security, and development and conservation outcomes.

Partners

Designing, implementing and evaluating this meningitis-weather decision support system depends on working with a number of communities and partners – especially local communities – in a participatory process. First and foremost, we must bring together the meteorological and public health communities in Ghana; it is essential that we involve institutions and people with local knowledge and resources in the design of the system. In Ghana, we plan to approach the Navrongo Health Research Centre or the Kintampo Health Research Centre. On the meteorological side, we will build on our already strong relationship with Dr. Benjamin Lamptey, a Ghana native, former UCAR employee, and expert in weather prediction using numerical models, and approach the Ghana Meteorological Service. Finally, to lay the groundwork for

extending these efforts across the subcontinent in the future, we will explore the possibility of partnering with the African Centre for Meteorological Applications for Development (ACMAD) to generate and disseminate meningitis-relevant forecast data in a process modeled on the successful Regional Climate Outlook Forum Program.

Three key personal for this proposal are to be based in Africa. The first is already identified: Benjamin Lamptey, who will collaborate closely with both the U.S. based modeling team and the Ghana-based team of health and weather experts on development and best use of forecast products for use by the health community in Ghana. A second African scientist will be supported to help with epidemiological data collection—both in accessing historical data, and recovering current data—as well as with management and design and use of the decision support system. Lamptey and the health scientist will work together with the proposal team on the development of risk-maps that integrate weather and epidemiological forecasts, and on the dissemination of these maps within Ghana. Finally, a health economist from Africa will help in the economic evaluation of the decision support model implementation.

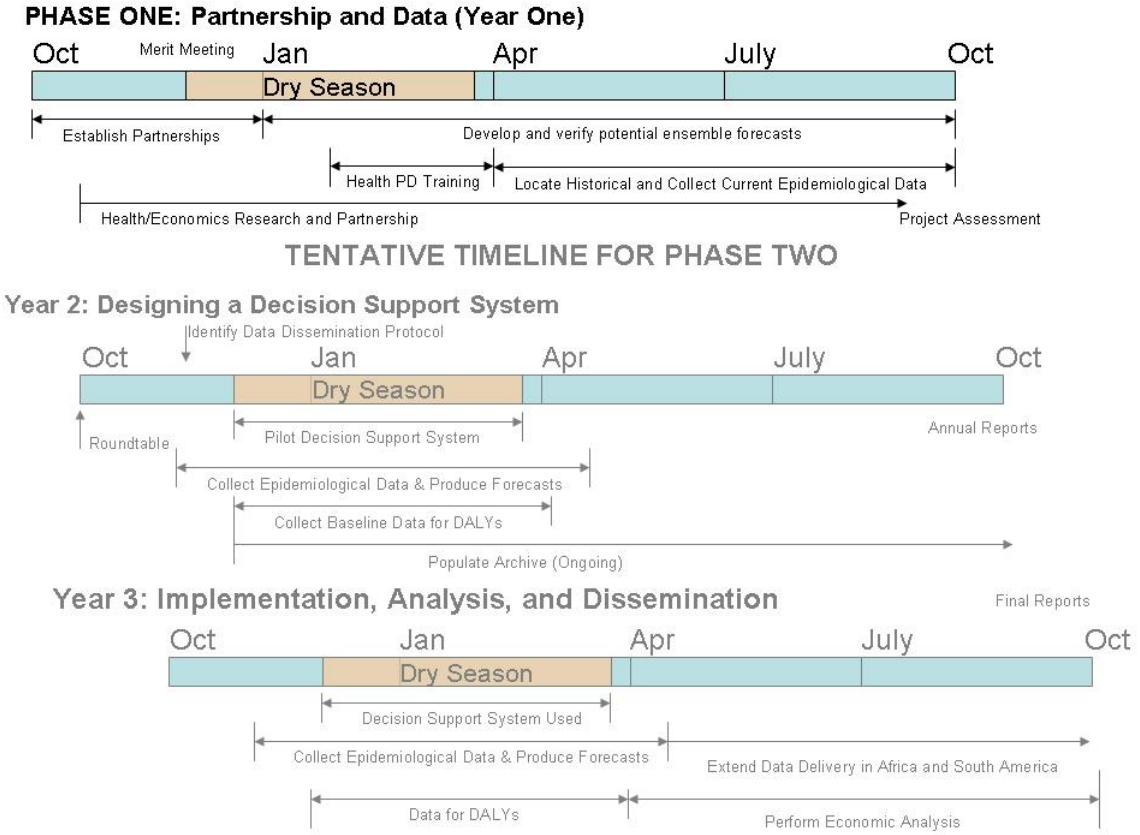
We will also engage with a number of partners outside of Africa. To complement UCAR's strong expertise in weather and climate with equally strong expertise in health, we have already arranged to work with International Research Institute for Climate and Society (IRI). Within the United States, PI Fred Semazzi at North Carolina State University will help connect our efforts with those of the U.S. university community. Internationally we intend to align our efforts with ongoing research on the climate/weather and health interface by the International Center for Theoretical Physics (ITCP) and the World Meteorological Organization (WMO). In WMO, the Thorpex program, its TIGGE ensemble of global models, and its connection to meteorological centers throughout Africa, are especially relevant to the project. Perhaps most importantly, we plan to apply to the steering committee of the Meningitis Environmental Risk Information Technologies (MERIT) program to be a partner in this effort.

Timeline (October 2008-October 2011)

The proposed work will be accomplished in two phases. The first phase will include development of local partnerships and collection of the data necessary for the second phase: the collaborative design, implementation, and preliminary evaluation of a weather-meningitis decision support system in Ghana. Because so much of the activities in Phase Two depend on the results of Phase One, timelines for Phase Two are presented in broad terms, and should be regarded as a first approximation subject to revision.

Phase One: Preliminary Partnership and Data (Oct 2008-Sept 2009)

The first year will be devoted to partnership building, preliminary data collection, and hypothesis testing to ensure the feasibility of using weather data to manage meningitis. This comprises a number of critical steps, and success beyond the first year depends on achieving these milestones.



First, we will develop the partnerships that will support the collection and archiving of necessary epidemiological data. The MERIT meeting, in December of 2008, will allow the project team to reach out to the community, explore previous experiences, and incorporate what is already known into the project. Working with MERIT and IRI, we propose to collaborate with either Navrongo or Kintampo to hire a Health Scientist, who will be trained at IRI and UCAR, and will work to collect, locate and archive appropriate epidemiological data related to meningitis in Ghana. These partners will also help identify current decision systems for reactive and proactive vaccination for epidemic meningitis. As part of this effort, we will be seeking the endorsement of public health services in Ghana, which is critical to the success of overall the project.

Second, we will work with Ben Lamptey to explore the forecast capability of an ensemble approach. Ensemble refers to the collection of global forecast models, with slightly different initial conditions, which can be used to predict future weather as well as its uncertainty. WMO has developed three archives to collect these ensembles and make them available to researchers; NCAR currently hosts one of the archives. While the ensembles are typically fairly coarse resolution and can have difficulty with locally-driven circulations, we think they may be useful in predicting large-scale circulations that are likely to be relevant to meningitis. To aid in verification of the ensemble forecasts, we will partner with the Ghana Meteorological agency. Also, during this year we will leverage current UCAR data management software to create and populate an archive of meteorological data.

Third, using the meteorological and epidemiological data, we will work with our partners to identify meteorological indicators for the meningitis season/epidemic

(including first case, threshold, peak, onset, and cessation) and establish the predictability of these meteorological indicators. For example, meningitis epidemics in many regions end abruptly with the beginning of the rainy season, so upward shifts in relative humidity is a good candidate for a meteorological indicator.

Fourth, a university-liaison advisory committee lead by Fred Semazzi will provide linkage with the international university community and provide oversight for a 'test-bed' project for refinement of the ensemble prediction products for the meningitis vaccination campaign. The purpose of this is to provide a pathway for assimilating the most current knowledge and expertise in the field from the broader community. The committee will operate mainly via email and conference calls, and it will include, in addition to Semazzi, Tom Warner, Thomas Hopson, Kerry Cook (Cornell), Arlene Laing (NCAR), Ben Lamptey, and representatives from the Ghana Meteorological Service, ACMAD, WMO, and ITCP. Semazzi and his student will perform the core development activities for the implementation of the committee's recommendations.

Fifth, we will begin exploring strategies to perform an economic analysis of the meningitis-weather information delivery. This will include forming partnerships with an African health-economist, investigating potential methods and protocols, and developing techniques appropriate to Africa and the proposed work.

If these partnership building efforts are successful, and the data for meningitis are available, we will end Year One with the following milestones:

1. A set of local institutions eager to partner in the design and implementation of a weather-meningitis decision support system; this will include the endorsement of public health officials in Ghana
2. A robust collection of meningitis and weather data for Ghana
3. A set of critical meteorological variables that correlate with meningitis epidemiology of cessation, determined by comparing data of milestone (2)
4. A demonstrated skill in using ensembles to predict a range of meteorological variables, including the ones identified in (3) above
5. An understanding of the local context for the design, implementation and preliminary economic evaluation of a decision support system.

With these milestones, we mark a critical path toward the overall success of the project. Although we are confident in our ability to achieve milestone (4), the other four milestones, which depend on collaboration in Ghana and the existence of appropriate data, are less certain. If necessary, we can shift our regional focus to Niger, where IRI and MERIT have already forged local partnerships and located robust meningitis data for Phase Two. Because the ensemble results described in milestone (4) are valid for all of West Africa, we can shift focus without compromising this milestone.

Phase Two: Design, Implementation and Preliminary Economic Evaluation of a Weather-Meningitis Decision Support System.

Phase Two depends on the outcomes of Phase One, and particularly the insight and guidance of local partners. For this reason, the timeline below should be regarded as tentative, and will likely be adapted with input from partners identified in Year One. We will work with these partners to design and implement a decision support

system, including relevant capacity building; evaluate the economic impact through process indicators; and share knowledge and upscale positive results in the Meningitis Belt.

Year Two: Designing a Decision Support System (Oct 2009-Sept 2010)

Year Two will begin with a roundtable meeting of the project personnel including collaborating partners in Africa and the community of stakeholders in public health. The goal of this roundtable will be to sketch the outline of a system that will allow public health providers—from officials to field workers—to use meteorological data in their management of meningitis. This will be an end-to-end process, and we will work with partners to address not only the kinds of meteorological forecasts produced, but also how the forecasts are distributed and used to make disease management decisions. While we anticipate the Ghana Meteorological Service will play a key role in distributing the forecasts, we will also explore other avenues to ensure widespread distribution. We will also extend UCAR technology to support the development and dissemination of weather information to help distribute the appropriate products for the decision support system.

At the same time, we will work with an African Health Economist to design a survey and protocol for collecting the data that can allow us to tentatively quantify the impact of these forecasts in terms of Disability-adjusted Life Years (DALYs). We will use this protocol to collect baseline data during Year Two.

We will simultaneously work with all partners to identify an appropriate region or regions for a pilot trial. The pilot will occur at the end of Year Two; we will produce, distribute and model the use of an appropriate risk map in a small region to troubleshoot every step of the distribution process before implementation.

Finally, epidemiological data collection by a health post-doctoral (PD) student, who will work with Lamptey to refine ensemble forecasts for the meteorological indicators of Meningitis epidemiology, will extend through Years Two and Three.

Year Three: Implementation, Analysis, and Dissemination (Oct 2010-Sept 2011)

In October of Year Three, we will convene a second round table with a primary objective being to evaluate and improve the experimental system, and design the final system. This round table will also include capacity building on the system and use of weather forecast by health practitioners in the selected region.

In the dry season of Year Three, we will implement the decision support model in the selected region. We will create and deliver the decision support tools identified in the roundtable, and perform surveys to estimate their impact. The preliminary evaluation will be based on developing a DALY model as commonly used by the World Health Organization. This will require either the collection of value data from respondents, or the transfer of values derived in other studies. If there isn't sufficient real-time data (this would be a good outcome since it indicates low occurrence of meningitis), we will examine historical data to estimate the impact our forecasts might have had in previous epidemics. Finally, a repeat of the initial round table will ensure ongoing dialog between the health and weather/climate communities and allow the refinement of data tools in an iterative framework.

The end of Year Three will be devoted to project extension and dissemination. While we recognize that the use of climate and weather information depends on how well it corresponds to users' needs and that this makes it unlikely we can apply the overall project in new areas, we believe we can generalize elements of the overall process. For example, ways of by identifying strategies to engage with stakeholders and encouraging two-way communication between meteorological services and potential users can be used to inform other projects or project activities. In addition, there are specific project activities that should be amenable to application elsewhere. First, our implementation of the decision support model will allow us to identify key areas for improvement in the actionable combination of meteorological and health information. For example, this may mean that the most impact on disease management is not from improved forecast, but from improved dissemination and use of forecasts. Second, we will identify a strategy for using ensemble methods to forecast health-related weather anywhere in the world, and we will also document the shortcomings of the ensemble approach used in Ghana, which may help define the phenomena and areas that require higher-resolution models. Third, we will outline ways to extend the decision support model into a more developed prototype Earth-gauging framework. This will include exploring how to integrate additional meteorological and climate data and include future climate change scenarios, as well as investigating the link between environmental changes and human health. We will also outline ways to leverage existing UCAR data distribution networks active in Brazil to extend the decision support model to health-related climate risks in central and South America.

Benefits of starting small and local

This proposal emphasizes small-scale partnerships and a focus on Ghana, instead of wide-scale capacity building. Also, it emphasizes better use of existing, global-scale ensembles before investing in high-resolution numerical modeling. This approach offers some key advantages and protections against uncertainty. First, it allows us to identify the key points at which we can invest to improve public health meningitis outcomes by using weather data. It may be, for example, that the largest hurdle involves not the current forecast, but communication barriers – including technological – that inhibit the forecast use. Second, before investing in high-resolution weather prediction, it makes sense to define the conditions under which these predictions add the most value. Using ensembles, and identifying where they fail, allows us to do that. Third, a slower start allows UCAR to develop additional collaborations and partnerships, and shields against the risk of building a major effort on an untested collaboration. Finally, and perhaps most importantly, this proposal is built on the well-supported but still unproven hypothesis that improved weather data can improve public health outcomes in the case of meningitis. This approach allows us to carefully test this hypothesis, and even evaluate the importance of weather and climate change relative to other variables that impact meningitis transmission.

Outcomes, Outputs, and Activities

We present here a tentative set of outcomes, subject to modification as part of our collaboration with local partners in Ghana.

Overall Outcome: We will work with African and international partners to save lives and enhance livelihood in Ghana by integrating weather and health data to better manage Meningitis.

Outcome 1: An Earth-gauging prototype that integrates weather and epidemiological data and supports improved management of meningitis

Output 1: Decision support model for meningitis management

Activity 1: Attend MERIT meeting (Hopson, Hayden, Semazzi, Lamptey, Health PD, Lazo) (December, 2008)

Activity 2: Establish partnerships and formal agreements (Pandya, whole team) (February, 2009)

Activity 3: Convene a round table in Ghana, bringing together health workers, regional health expertise, meteorologists, and atmospheric scientists. (Whole team + Thomson) (October, 2009)

Output 2: New forecasts derived from Ensembles that are useful to Meningitis management

Activity 1: Develop and verify potential ensemble forecasts for meningitis (Preliminary investigation prepared for roundtable (January-August 2009), refinement after roundtable (September 2009)

Activity 2: Prepare pilot forecasts (Hopson, Lamptey) (Dec 2009-March 2010)

Activity 3: User conferences after pilot (Hopson, Lamptey) May 2009

Activity 4: Integrate forecast products into decision support model, with user feedback and training (Hopson, Lamptey) (December 2010-March 2009)

Activity 5: Collaborative customization of ensemble prediction products (Semazzi and university liaison committee (Ongoing))

Output 3: Enhanced meningitis data in Ghana

Activity 1: Health PD at UCAR and IRI for training, collaboration (Hayden, Thomson) (February-April, 2009)

Activity 2: Locate and rescue existing records (Hayden, Thomson, Health PD) (April-October, 2009)

Activity 3: Set up surveillance protocol arrangements and collect new data (Hayden, Health PD) (October 2009-March 2011)

Output 4: Earth-gauging prototype that assembles, distributes, and archives data.

Activity 1: Prepare archive for weather data, leveraging Unidata's Thematic Realtime Environmental Distributed Data Services (THREDDS) technology (Lamptey, Yoksas) (September 2009)

Activity 2: Look at suitability of THREDDS for epidemiological data (Health PD, Yoksas) (September 2009)

Activity 3: Develop and Populate archive (Hayden, Semazzi, Health PD, Hopson) (December 2009-May 20011)

Activity 4: Identify protocol and technology for health/weather communication (same as above + Yoksas for advising on Unidata's Integrated Data Viewer (IDV) use in product generation) (November 2009)

Outcome 2: A strategy to apply what is learned in Ghana more generally

Output 1: Economic Evaluation of the Decision Support Model

Activity 1: Baseline data collection (Dec 2009-March 2010) (Lazo, Health Economist)

Activity 2: Data collection during implementation (Dec 2010-March 2011) (Lazo, Health Economist, Hayden)

Activity 3: Analysis and Reporting (Lazo, Health Econ) (March 2011-August 2011)

Output 2: An extensible data-archive and distribution protocol for integrating health and weather data.

Activity 1: Leverage Unidata/Internet Data Distribution (IDD) to assimilate and disseminate data in Africa (Begin April 2011)

Activity 2: Extend the data assimilation and dissemination network to Brazil (Begin April 2011)

Activity 3: Disseminate Earth-gauge tools developed for weather-epidemiology integration (based on IDV in GoogleEarth) (Yoksas, Lamptey, Health PD) (Begin April 2011)

Output 3: Disseminate recommendations and lessons

Activity 1: Document protocol for developing disease relevant forecasts from ensemble methods (Hopson, Lamptey, Semazzi) (Ongoing, updates in Oct 2009, 2010, 2011)

Activity 2: Disseminate strategies and lessons for implementing Health-Weather decision making (Hayden, Thomson, Semazzi) (Ongoing, updates in Oct 2009, 2010, 2011)

Activity 3: Disseminate a protocol for economic evaluation of weather-forecasting for health (Lazo, HealthEcon) (April-October, 2011)