BAMS
Meeting Summary

Developing an Experimental Climate and Health Monitor and Outlook

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Climate and Health Monitor and Outlook Workshop

What: The U.S. Global Change Research Program convened a workshop to explore the prospect of and process for producing experimental seasonal climate and health outlooks for the United States through consultation with leading experts in vector- and water-borne disease prediction.

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The U.S. Global Change Research Program (USGCRP) Climate and Health Monitor and Outlook (CHMO) workshop convened 23 experts in climate and health from government and academia to understand how existing climate and health prediction systems for specific diseases, vectors, and pathogens are producing and sharing information for health decision-making.

The principal goal of the workshop was to understand how a national, integrated climate and health outlook, focused on vector-borne diseases, could be developed to support public health decision-makers in managing health risks. The CHMO workshop enabled the group to incorporate lessons and information from the many existing disease prediction systems across the nation to discuss how to create a consistent national view of potential health impacts from predicted future climatic conditions. This workshop summary synthesizes our discussion, captures a table of datasets and products that the CHMO can draw upon to characterize important aspects of climate-sensitive disease risk, and suggests a set of next steps to achieve progress in predicting these risks.

This 1-day workshop sought the following outcomes:

- A survey of existing climate and health impact prediction activities
- A synthesis of lessons learned as well as opportunities and barriers to producing an experimental seasonal prediction for health
- Improved understanding of the relationship between major climate signals and health impacts based on regional and local knowledge, and the underpinning research basis
- Exploration of how new and existing climate products and datasets could contribute to a national–regional seasonal health outlook

This workshop drew from years of planning and exploration of this topic area by many government agencies—through meetings such as the USGCRP workshop on “Predicting Climate Sensitive Infectious Diseases to Protect Public Health and Strengthen National Security” (USGCRP 2019) and the long-running Pandemic Prediction and Forecasting Science and Technology Working Group—as well as decades of grant-supported research and experimentation into the prediction of climate-sensitive infectious diseases. It was informed by several existing health-relevant products and services such as the Famine Early Warning Systems Network (FEWS NET), and the Caribbean Health Climatic Bulletin (https://rcc.cimh.edu.bb/caribbean-health-climatic-bulletin/).

The need for a Climate and Health Monitor and Outlook

The CHMO addresses a long-standing need for integrated environmental information for health decision-making. As the climate system warms, extreme climate and weather events are expected to become more frequent and intense (USGCRP 2018), driving an increase in health impacts (Mora et al. 2018). The most recent *Lancet* Countdown report, which tracks a set of climate and health indicators over time, has observed that the climate suitability for the transmission of diseases such as dengue fever, and vibriosis is increasing as land and ocean temperatures warm. Increasing temperatures also increase the risk of heat-related illness (Watts et al. 2019).

The links between climate and vector- and water-borne diseases are illustrated by the classic epidemiologic triad: environment–agent–host. The environment is the land or water habitat within which ticks, mosquitos, and other carriers of disease can survive, or within which the pathogen itself (such as *Vibrio* bacteria) might survive. Vectors—the disease carriers—are considered a part of the environment; thus, their survival, behavior, and range are dependent on the environmental conditions that are affected by climate variability and change. The agent (pathogen) also might be sensitive to changing environmental parameters. For example, colder temperatures slow bacterial growth. Finally, our host of concern (humans) must be exposed to the pathogen, from the vector, through the environment, to complete the cycle and cause infection.

Modeling disease dynamics is complex because environmental changes, human behavior (including interventions to manage disease), vector behavior, and pathogen genetics interact in many ways. Fortunately, interrupting a link at any step along this pathway can help to manage climate-sensitive infectious diseases.

Models of climate-sensitive infectious diseases can improve early warning and inform prevention and preparedness measures, such as prepositioning of medical supplies, temporary shelters, and other assets. Ultimately, this can hasten detection of outbreaks and reduce the burden of disease associated with epidemics (Morin et al. 2018). However, even with improved early warning systems, many public health departments across the United States lack expertise in accessing and applying climate and weather predictions for health planning and preparedness [National Association of County and City Health Officials (NACCHO); NACCHO 2014]. The CHMO aims to close this gap by integrating available information and displaying it in new ways that provide tailored, understandable, and useful predictions for public health experts and workers.

The CHMO prototype was launched in the spring of 2019 as a pilot activity aimed at building strong relationships with health users—understanding their needs and defining the demand for enhanced climate and health information for decision-making. Initial climate and health impact targets include extreme heat, arboviral diseases, and waterborne diseases caused by *Vibrio* bacteria. These targets were selected after consideration of current environmental prediction capabilities and grantee research outcomes from federal programs in NOAA, the National Institutes of Health, the Centers for Disease Control and Prevention, and NASA. This inaugural CHMO workshop was organized by the USGCRP Climate and Health Interagency Working Group to draw on the expertise of grantees who have developed and worked with climate and health predictions for health users.

A workshop to advance the CHMO

The CHMO workshop began with presentations on existing efforts to understand, predict, and communicate climate-sensitive health risks. The following prediction systems were represented:

- The Experimental National Integrated Heat Health Information System (NIHHIS) Monitor and Climate Health Outlook
- The Caribbean Health Climatic Bulletin
- FEWS NET
- Arbovirus Modeling and Prediction (ArboMAP) West Nile Virus Prediction System
- NOAA National Centers for Coastal Ocean Science Vibrio predictive models
- The California Vectorborne Disease Surveillance Gateway (CalSurv)
- U.S. Air Force 14th Weather Squadron predictions
- Northeast Regional Climate Center mosquito forecasts

- Columbia University West Nile virus forecasts
- NOAA Climate Prediction Center seasonal outlooks

After the presentations, the group discussed a variety of critical datasets (Table 1) and potential products (Table 2) for the CHMO team to explore.

Many of the datasets identified in Table 1 are already available, but not integrated, not provided at health-relevant scales, not consolidated or readily obtainable, and not well understood

Table 1. Data needs identified by climate and health experts during the Climate and Health Monitor and Outlook workshop.

Datasets to develop or improve	Climate–health linkage
Growing degree-days (GDDs)	GDDs approximate days with favorable ecological conditions for vector emergence, reproduction, and survival.
Land surface wetness (integrating water table, precipitation, vegetation response, etc.)	Land surface wetness is an indicator for favorable conditions for vector emergence.
Vector–host collocation (human population distribution and land use)	Overlap of human and vector habitat indicate increased likelihood of exposure, and thus, transmission of disease.
Climate data regridded at health-relevant scales	Public health jurisdictional boundaries differ from climate regions, and often finer-scale information is needed.
Cumulative temperature load (No. of days in a range)	Vector emergence is often conditioned on a certain number of days with favorable temperatures. Also, temperature modulates the external incubation period for pathogens in vectors.
Accumulation of cooling degree-days (CDDs) above a threshold	CDDs approximate favorable temperatures for vectors and pathogens to survive and reproduce or replicate.
Cooling degree-day prediction for winter and spring	CDD prediction can be used to approximate the duration of favorable temperatures for pathogens and vectors and can suggest the number of life cycles for a season.
Vector thermal performance curves	Thermal performance curves show the optimal temperature for specific biological rate processes, such as reproduction.
Historical seasonal skill maps for temperature and precipitation predictions	Seasonal skill maps indicate when predictions typically have high or low skill and can indicate when a prediction may be more or less accurate for informing a decision.
Query-able database and gridded map of monthly and seasonable probability of exceedance (PoE) curves	PoE information calculated by the NOAA Climate Prediction Center should be available in standard formats that can be queried from a database or spatial (GIS) web service.
Number of days above a specific temperature during a period	The number of days exceeding a threshold, such as the optimal reproduction temperature for a mosquito species.
Integrated winter–spring–summer view	An integrated dashboard of the winter anomaly plus predicted summer anomaly can be used to infer how severe the season's vector-borne disease caseload might be.
Irrigated agriculture (rice flooding)	Irrigated agriculture can create vector habitat. Understanding where it is and how much moisture it contains can be an indication of its suitability to host vectors.
Spring soil moisture anomaly (growing conditions)	A strong negative or positive soil moisture anomaly is sometimes correlated with a greater number of disease vectors.

by the health community. Additionally, the potential products identified in Table 2 may be available in some form for some areas but would require extensive research and development to be available and useful at a national scale. Many potential climate and health products and services are not developed because their scope spans environmental agency and health agency missions, so there is no clear lead agency required to produce them. The CHMO's interdisciplinary team is working to address these issues.

The afternoon session began with an exercise in which participants interpreted the health implications of several seasonal climate outlooks (temperature, precipitation, drought). A goal

Table 2. Prototyping needs identified by climate and health experts during the Climate and Health Monitor and Outlook workshop.

Potential products to prototype	Description
Endemicity trackers (mosquitos, ticks, *Vibrio*)	Indicator tracking current modeled spread of endemic vectors based on climate conditions.
Vector danger rating system (high sensitivity, low specificity)	A summary view (similar to fire danger ratings) indicating the expected severity of the season in terms of habitat suitability, vector population, or case counts.
Disease onset probability	The probability of cases of a disease being diagnosed in a given period—used to determine the start of a seasonal disease.
Epidemic peak timing	The moment when case counts for a disease will most likely peak.
Epidemic length	The duration of a disease season.
Geographic distribution of epidemic	The predicted or observed geographic spread of a particular outbreak of disease, such as the local spread of an imported virus (e.g., dengue).
View of annual extremes to spot check West Nile virus outcomes	A new view of annual extremes, perhaps derived from National Centers for Environmental Information climate rankings, could be used to compare climate anomalies with disease outcomes (such as West Nile virus) if rescaled to needed spatial and temporal scales relevant for health.

of the exercise was to produce an example of a climate and health outlook as a framework for discussion about practical matters of implementation. Instead, the complexity of such an interpretation exercise became immediately apparent. Participants began to suggest additional datasets that could support such a task. They also shared ideas about the form and function of potential national-scale products that could come from such datasets.

Workshop discussion and key outcomes

Considerable discussion focused on the importance of knowing the audience for the CHMO product. The public health realm alone encompasses many groups with varied roles and information needs. Some, for example, are involved in tracking disease to apply interventions. Others are technologists developing surveillance systems. Furthermore, each locality and state may structure their health department and services differently. Levels of coordination between the health departments and vector control agencies differ. Local regulations differ. Opinions on use of climate-scale predictions also differ.

After determining the audience, attention must turn to the health risks to be prevented and the information needed to intervene. Opportunities to manage climate and health effects abound along the chain of infection. Predicting hydrological and temperature extremes, for example, can guide decisions on when and where to reduce standing water or manage dry underbrush. To better manage disease vectors, predictions can guide the timing and approach for applying larvicide or communicating practical information to residents. Earlier warnings give us more time and information to preposition and administer prophylactic interventions. Predictions also can help public health professionals decide when to send targeted messaging to alter human behaviors, such as increasing use of mosquito repellant.

Decision-supporting predictions can be driven by many types of models of many types of outcomes. Ecological suitability and habitat models of the vectors suggest where vectors may be found and how they might spread. Infectious disease models can predict epidemic onset, duration, and peak. Some hybrid models can predict even more complex and potentially health-relevant values, such as the transmission potential of disease. Each of these prediction targets has pros and cons, which must be considered, including prediction skill, complexity, and applicability.

Acceptance and use of a product is dependent on user trust in its accuracy as well as trust in those producing the information. Many public health offices have a strong local focus, and might first look to locally or regionally tuned products rather than using less specific information provided by the federal government. Products codeveloped with intended users might be more readily accepted at the local level. Some users might see added value in products offered in cooperation with member organizations such as the National Association of County and City Health Officials or the American Public Health Association. A good example of how to increase product acceptance and use comes from CalSurv, which designed state-level reports to draw upon local data. The enhanced reports are most useful to local decision-makers if they include the local data, creating an incentive for local agencies to share their data with the state in order to make the best use of the advanced products.

A critical outcome of the discussion was addressing the role of a broadly scoped, federally developed, national climate and health outlook, given the importance of accurate, locally relevant information for taking action. Participants envisioned the CHMO as a national dashboard providing access to highly tuned regional and local products, such as those shown earlier in the day. In effect, the CHMO could be a mosaic of detailed predictions and could generate broader key messages for health users from a national perspective. Thus, the CHMO could perform a basic education function. It could essentially help public health departments to broadcast scientifically sound messages about the health effects of climate and increase health practitioner confidence in using climate information. The CHMO product could raise awareness and promote early action while the local prediction systems focus on providing specific information for targeting those early actions. The process of building partnerships and codeveloping high-level messages for the CHMO could also strengthen the access health practitioners have to climate information and expertise.

The CHMO workshop reaffirmed the value of a high-level climate and health outlook, produced in concert with a broad set of public health users. Such a product could increase public awareness of climate and health effects and support local decision-making by consolidating targeted information from established products. Participants noted both integration of retrospective climate observations and public health surveillance, as well as provision of predictive climate information and health interpretations, as important goals for the CHMO to support managing health outcomes in a variable and changing climate.

Immediate next steps for the CHMO include cataloging existing climate–health prediction tools and developing health sector user relationships through regional workshops and engagement of public health organizations and associations. They also include technical development and integration of identified datasets to make them more useful for health decision-making and development and refinement of potential prototypes of the CHMO.

More broadly, next steps for federal climate and health programs include advancing the science of climate and health effect prediction by cultivating research to address opportunities and gaps identified in this workshop. They also include seeding review papers on specific topics, such as West Nile virus prediction, and convening modeling experts on a regular basis to keep them abreast of CHMO efforts.

Finally, for long-term continuity, the CHMO team can explore inclusion with existing climate outlook forums and regional products (such as the Rio Grande/Bravo Climate Outlook) and international expansion through partners such as the Pan American Health Organization (PAHO).

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References

Mora, C., and Coauthors, 2018: Broad threat to humanity from cumulative climate hazards intensified by greenhouse gas emissions. *Nat. Climate Change*, **8**, 1062–1071, https://doi.org/10.1038/s41558-018-0315-6.

Morin, C. W., J. C. Semenza, J. M. Trtanj, G. E. Glass, C. Boyer, and K. L. Ebi, 2018: Unexplored opportunities: Use of climate- and weather-driven early warning systems to reduce the burden of infectious diseases. *Curr. Environ. Health Rep.*, **5**, 430–438, https://doi.org/10.1007/s40572-018-0221-0.

NACCHO, 2014: Are we ready? NACCHO Rep. 2, 57 pp., www.naccho.org/uploads/downloadable-resources/NA609PDF-AreWeReady2.pdf.

USGCRP, 2018: Impacts, risks, and adaptation in the United States. Vol. II, *Fourth National Climate Assessment*, D. R. Reidmiller et al. Eds., U.S. Global Change Research Program, 1515 pp., https://doi.org/10.7930/NCA4.2018.

——, 2019: Predicting climate-sensitive infectious diseases to protect public health and strengthen national security. USGCRP Rep., 15 pp., www.globalchange.gov/sites/globalchange/files/Predicting_ClimSensInfDisease_2019.pdf.

Watts, N., and Coauthors, 2019: The 2019 report of the *Lancet* Countdown on health and climate change: Ensuring that the health of a child born today is not defined by a changing climate. *Lancet*, **394**, 1836–1878, https://doi.org/10.1016/S0140-6736(19)32596-6.