Discussion Paper for National Climate Assessment

Environmental Health Indicators for Climate Change

As part of the Climate Change Indicators Subcommittee of
The Council of State and Territorial Epidemiologists (CSTE)
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Summary
The National Climate Assessment (NCA) anticipates that climate change indicators will be selected as part of their process to "increase understanding of rates of change, thresholds, etc. in support of decision making." Therefore we present a synthesis of the latest research of environmental health indicators of climate change, and recommendations for future development of these measures.

I Background

Indicators are quantitative summary measures that can be used to track changes in conditions by person, place, and time. The State Environmental Health Indicator Collaborative (SEHIC), a subcommittee of the Council of State and Territorial Epidemiologists (CSTE), described environmental health indicators as elements of environmental sources, hazards, exposures, health effects, and intervention and prevention activities which can be used to assess positive and negative environmental determinants of health. Climate Change Environmental Health Indicators can be used to:

- Assess human health vulnerability to climate change
- Identify disease thresholds of weather factors in different geographic regions
- Identify areas for intervention and prevention
- Evaluate the outcomes of specific policies or programs aimed at improving public health.
- Promote development of dose–response models
- Identify populations at risk through tracking risk factors and population susceptibility
- Predict disease burden for public health planning and intervention
- Serve as important communication tools for making environmental health information available to stakeholders, including environmental health practitioners, partners, policy makers, and the general public.

The National Climate Assessment (NCA) anticipates that climate change indicators will be selected as part of their process to "increase understanding of rates of change, thresholds, etc. in support of decision making." Therefore we present a synthesis of the latest research of environmental health indicators of climate change, and recommendations for future development of these measures.

II Synthesis of Literature

Measures of environmental health indicators for climate change have been developed, including efforts by the WHO/Europe, U.S. Environmental Protection Agency (U.S. EPA), the National Research Council, California EPA, and the climate change indicator subcommittee of the Council of State and Territorial Epidemiologists (CSTE).

World Health Organization/Europe

In 2009, WHO/European Centre for Environment and Health held a symposium on "Development of Health-Relevant Climate Change Indicators." Eight indicators were agreed upon: (1) Excess mortality to heat waves; (2) Flooding; (3) Population Vulnerability to Flooding; (4) Ozone air quality; (5) Airborne pollen/allergens; (6) Salmonellosis incidence; (7) Cryptosporidiosis incidence; and (8) Lyme borreliosis incidence (Dalbokova, et al. 2009)

U.S. EPA

The 2010 Report: "Climate Change Indicators in the United States" had one measure directly relevant to human health in the "Society and Ecosystems" chapter: Heat-Related Deaths. Heat-related deaths were defined in this measure as those in which heat was the underlying cause of death on the death certificate. (U.S. EPA, 2010)

National Research Council (NRC)

In 2010, the National Research Council published "Monitoring Climate Change Impacts," which examined metrics of climate change, human vulnerability and earth system on a global level (NRC, 2010). Human health metrics included disease transmission, incidence of respiratory disease, waterborne disease, and environmental health.

California EPA (Cal/EPA)

The 2009 report: "Indicators of Climate Change in California" has two measures which are directly relevant to human health: heat-related mortality and morbidity and mosquito-borne diseases (California EPA, 2009). The report ranked heat-related mortality and morbidity as a Type III indicator ("no ongoing surveillance") and mosquito-borne diseases as a Type II indicator ("full or partial data but further analysis needed"). Cal/EPA also issued a supplemental report in 2010 (California EPA, 2010) focusing on environmental justice impacts which identified four more measures with direct relevance to human health: air conditioner ownership and cost; farm worker exposure to extreme heat; exposure to urban heat; and vulnerability to wildfires.

Council of State and Territorial Epidemiologists (CSTE)

The CSTE climate change indicator subcommittee published a 2009 paper entitled, "Environmental Health Indicators of Climate Change for the United States" (English, et al. 2009) (Appendix A). This paper proposed 27 indicators in six categories: Environmental, morbidity and mortality, vulnerability, mitigation, adaptation, and policy. These formed the basis for the development and pilot testing of 25 climate change indicators (Table 1). The CSTE subcommittee then developed how-to guides to complete each proposed climate change indicator. CSTE funded three states and one municipality (Illinois, Montana, North Carolina, and Washington, District of Columbia) to compile data to evaluate the suite of indicators and an additional seven states participated in the pilot without funding from CSTE. All jurisdictions compiled data following the guide, and completed an assessment that addressed the time

frame required to complete each indicator, perceived usefulness of the proposed indicators, and the likelihood of these indicators being adopted by the state's health department. Additional information about the CSTE pilot is available on request.

CDC /National Environmental Public Health Tracking Program

The CDC's National Environmental Public Health Tracking Program (NEPHT), which started in 2002, integrates data on environmentally related health, hazards, and exposures. A variety of health, hazard, and exposure indicators have been developed by CDC and the states funded by CDC, and these data are posted on the CDC NEPHT portal. Recently NEPHT added three climate indicators including heat vulnerability, heat-related mortality, and temperature distribution to its public portal (http://ephtracking.cdc.gov/showClimateChangeLanding.action). NEPHT is also recommending that excess mortality/morbidity be calculated for heat wave events.

Table 1: CSTE Climate change indicators used in 2011 pilot

Environmental Indicators	
1	Greenhouse Gas Emissions
2	Air Mass Stagnation Events
3	Max/Min and Diurnal Temperature
4	Pollen Indicator
5	Number of fires and percent of total acres impacted by state
6	Positive test results in sentinels and reservoirs
Health Outcome Indicators	
7	Rate of heat deaths, hospitalizations, and emergency room visits during summer months
8	Injuries and deaths due to extreme weather events
9	Human cases of Lyme disease
10	Human cases of West Nile Virus
11	Human cases of valley and dengue fever, Hantavirus
12	Allergic disease related to climate change
Mitigation Indicators	
13	Total energy consumption per capita
14	Renewable energy consumption per capita
15	Vehicle miles traveled
Adaptation Indicators	
16	Development of a state adaptation plan
17	Access to cooling centers
18	Heat island mitigation plans
19	Health surveillance systems related to climate change
20	Public health workforce trained in climate change research, surveillance, and adaptation
Policy Indicators	
21	Development of a state climate change advisory board
22	Development of a state climate change action plan
23	Completion of a greenhouse gas inventory
24	Number and percent of local governments participating in ICLE
25	Percent of Population living in cities participating in the U.S. conference of mayors climate protection agreement

Table 2 compares the recommended indicators in each of the reports listed above.

Table 2: Comparison of Reports with Human-Health Relevant Climate Change Indicators

Report	Environmental Exposures	Human Health Outcomes	Population Vulnerability	Other
WHO/EU	Ozone; pollen	Food, water, and vector-borne disease	Flooding	None
NRC	Heat; drought; flooding; ozone; pollen; wildfire; harmful algae blooms	Disease transmission; respiratory disease; waterborne disease	Living in vulnerable areas; migration; Elderly living alone; infant mortality	Earth systems
U.S. EPA	Heat; drought; extreme weather	Heat-related deaths	None	Ecosystems
CSTE	Same as NRC	Mortality/morbidity due to heat; deaths/injuries due to extreme weather; Environmental infectious disease; Respiratory disease	Heat; flooding; sea level rise	Mitigation; adaptation; policy
Cal EPA	Heat; sea-level rise	Heat-related mortality/morbidity; mosquito-borne illness	None	Ecosystems; environmental justice

III Criteria for selecting indicators/frameworks in referenced reports

These reports have chosen different approaches for selecting indicators. The U.S EPA had a set of screening criteria that considered usefulness, objectivity, data quality, transparency, ability to show a meaningful trend, and relevance to climate change. The National Research Council selected indicators based on "[how] it must inform how climate change affects the five domains of human vulnerability: water, food, energy, health, and shelter." Cal/EPA selected climate change drivers, measures which indicate changes in climate, and those which indicate climate change impacts. They classified the indicators based on availability of data. CSTE selected indicators which measured current vulnerability to climate variability and change or measures of environmental variables that can directly or indirectly affect human health. Indicators were also selected to track possible changes in health outcomes to determine if climate change is actually affecting their geographic range and incidence. Screening criteria included data temporality, completeness, and availability.

Hambling et al. (2011) reviewed various frameworks for establishing environmental health indicators of climate change and recommended the Driving force-Pressure-State-Exposure-Effect-Action (DPSEEA) framework as established by the WHO. They conclude that the DPSEEA framework shows the links "between exposures and health effects as determined by many different factors operating through a chain of events, and clearly shows the many entry points for interventions".

IV Current State of Readiness of our Proposed Indicators

Table 3 lists selected proposed indicators from all the sources listed above for overall readiness for implementation. We have only included those indicators that meet the highest standards considering data quality/completeness, availability, temporality, and the sensitivity of the measure to public health effects. Even among these selected indicators, some are at a better state of readiness than others, thus each indicator is assigned one of three categories of readiness: high, medium, or low. The rationale for these selections and limitations to these proposed indicators follow.

Table 3: Evaluation of Overall Readiness for Climate Change Environmental Health Indicators for the U.S. (Excluding Adaptation, Policy, and Mitigation Indicators)

Measure	Data quality/Completeness	Availability	Temporality	Sensitivity*	Overall Readiness
Environmental					
Extreme heat	High	High	High	High	**High**
Stagnation air mass events	High	High	High	Medium	**High**
Increases in ozone due to climate change	Based on modeling; downscaling issues	Low	High	Medium	Low
Pollen counts	Low	Low	UK	Medium	Low
Wildfires	High	High	High	High	**High**
Drought	High	High	High	Medium	**High**
Harmful algae blooms	Medium	Medium	Medium	Medium	Medium
Extreme weather events (other than heat)	Medium	Medium	High	High	**High**
Human Health					
Excess mortality/morbidity to extreme heat	Medium	Low-med	High	High	Medium
Rate of Heat deaths/illnesses	Medium	Med-High	High	Medium	Medium
Injuries/Mortality from extreme events	Low	Low-med	Med	High	Low
Env. Infectious Disease (e.g. West Nile, Lyme, Valley Fever	High	High	High	Medium	Medium
Increased respiratory disease due to increased ozone/pollens	Based on modeling	Low	High	Medium	Low
Food-borne disease	Under-reporting	High	High	Low-med	Medium
Water-borne disease	Under-reporting	High	High	High	Medium
Vulnerability					
Flooding	Low	Low	N/A	High	Low
Wildfires	Medium	UK	N/A	High	Medium
Heat	High	High	N/A	High	**High**
Drought	Medium	Medium	N/A	Medium	Medium
Sea-level Rise	High	High	N/A	Medium	**High**

Note: * sensitivity to public health impacts due to climate change

A) Indicators with High Readiness for Implementation for Surveillance

1) Extreme Heat. This measure is at high readiness for surveillance but there is a lack of consensus on its definition. We are concurring with the definition recommended from the CDC Environmental Health Tracking Program, which is generally consistent with the scientific literature. This definition of extreme heat day is a day in May through (and including) September where the maximum temperature or heat index exceeds the 95th percentile for that day based on the 1971-2000 climate normal dataset (Anderson and Bell, 2010). The maximum temperature must exceed 85 degrees F and the heat index 90 degrees F. A heat wave is two or more extreme heat days.
2) Stagnation Air Mass Events. An air mass stagnation day is defined as one with sea-level geostrophic wind < 8 m/sec, 500 millibars (mb) wind < 13 m/sec, and no precipitation (Wang and Angell 1999), and although not directly related to pollutant emissions, air stagnation days can exacerbate the effects of existing air pollution. Air mass stagnation events are one of the climate impact indicators proposed by the National Climatic Data Center (NCDC) and are expected to increase O_3 production and will increase in frequency as weather conditions favorable to heat waves increase (CCSP 2008). Air mass stagnation events are available by request from the NCDC (2009).
3) Wildfires. Data from the National Interagency Fire Center (2009) can be used to monitor national wildfire trends. Recommended indicators include examining the frequency, severity, distribution, and duration of wildfires. Suggested measures include the annual area burned and the average yearly increase in the proportion of acres burned.
4) Drought conditions. Drought indicators should be monitored by public health officials because drought is associated with degraded water quality and quantity, waterborne disease, and food safety, among other concerns (Georgia Water Advisory Group 2007). There is no single indicator for drought. Several indices are available, including percent of normal, the standardized precipitation index (SPI), the Palmer Drought Severity Index, and the surface water supply index (SWSI) [National Drought Mitigation Center (NDMC) 2006]. The NDMC uses the SPI because it can project emerging droughts sooner than other indices. It is recommended that the SWSI be used in western states, where water quantity and quality are dependent on snow pack levels. Therefore, we recommend that the SPI and SWSI be used as climate change drought measures. Several web-based tools exist for monitoring drought and its effects, such as the NDMC's Drought Impact Reporter (2009), which monitors drought effects on agriculture, water/energy, environment, fire, and social factors. To assess the impact of drought on human populations, Falkenmark et al. (1989) used water scarcity (water supply < 500 m^3/person) and water stress (water supply < 1,000 m^3/person) as indicators.
5) Extreme weather events. Extreme weather events are available from the Spatial Hazard Events and Losses Database for the United States (SHELDUS, 2012). SHELDUS contains county-level hazard data for the U.S. for 18 different natural hazard events types such thunderstorms, hurricanes, floods, wildfires, and tornados that resulted in at least $50,000 in damages. For each event the database includes the beginning date, location (county and state), property losses, crop losses, injuries, and fatalities that affected each county.
6) Heat Vulnerability. Populations that have been found to have high vulnerability to heat mortality and morbidity include the socially isolated, children, the poor, and the elderly. Reid et al. (2008) conducted a principal component analysis to construct an index of community heat vulnerability at the census tract level, which combined vulnerability factors from the

U.S. Census with air conditioning data from the American Housing Survey and comorbidity data from the Behavioral Risk Factor Surveillance System (BRFSS).

7) Sea-level rise Vulnerability. The USGS has developed an index of coastal vulnerability to future sea-level rise, which incorporates tidal range, wave height, coastal slope, shoreline erosion rates, geomorphology, and historical rates of sea-level rise (Thieler 2000). Coastal vulnerability is ranked from low to very high. The coastal vulnerability index could be used with U.S. Census population data and boundaries for coastal census block groups for the contiguous United States to create a measure that provides a general indication of the population living in close proximity to high-risk areas.

B) Indicators with Medium Readiness for Implementation for Surveillance

1) Rates of Heat Deaths/Illnesses and Excess Mortality/Morbidity from Extreme Heat Events. The CDC's National Environmental Public Health Tracking Program (NEPHTP) will be soon requiring states participating in their program to track heat-related deaths, hospitalizations, and emergency room visits. Although these events are easy to identify based on the use of specific diagnostic codes, the full burden of mortality and morbidity from heat events are better estimated by computing overall excess mortality and morbidity. Data are available on a national scale from the National Center for Health Statistics to compute excess mortality from heat events; states would be able to compute excess morbidity from their data
2) Harmful Algae Blooms. A worldwide increase in cyanobacterial (blue-green algae) sources has been observed in both coastal and freshwaters (Hallegraeff 1993; Moore et. al. 2008). These harmful algae blooms (HABs), which produce nerve and liver toxins, are longer in duration, of greater intensity, and are suspected of being tied both to increased temperatures due to climate change and nutrient runoff. Human exposure is of concern through both drinking water contamination and recreational exposure. The National Center for Environmental Health (NCEH) has developed the Harmful Algal Bloom-related Illness Surveillance System (HABISS) to collect data on human and animal health and on the environmental effects of harmful algal blooms, which is currently active in 13 states. Assurance of continued funding for this program is unknown. The NEPHTP is currently considering adopting HAB indicators.
3) Environmental Infectious Disease. Climate change may affect the geographic range and incidence of several environmental infectious diseases, including West Nile encephalitis, Lyme disease, coccidioidomycosis ("valley fever"), dengue fever, and human hantavirus cardiopulmonary syndrome (HCPS). Data on many of these conditions are available through the CDC's ArboNET surveillance system. Since there are outstanding uncertainties on how these vectors may respond to changes in climatic conditions, this does not warrant a high readiness classification at this time.
4) Food-borne disease. That climate change may increase the incidence of food-borne diseases, especially Salmonellosis, has been of recent concern. However, the fact that cases of foodborne illness continue to be underreported and that there exists some disagreement on the impacts of increased temperature on disease risk causes this indicator to rank as medium readiness.
5) Water-borne disease. During extreme weather events such as heavy precipitation, waste water systems are often overwhelmed and sewage may contaminate drinking water sources

(Patz et al 2008). Waterborne disease such as gastroenteritis has been related to heavy precipitation events. Waterborne diseases continue to be underreported. We recommend this indicator at medium readiness.

6) Wildfire Vulnerability. Some states have identified communities at high risk for wildfires, primarily based on proximity to forested areas which have high potential to burn. However, due to the complexity of wind patterns and meteorology, population exposure assessment to wildfire smoke is still in its infancy. We therefore rank this measure as medium readiness.
7) Drought vulnerability. Vulnerable populations affected by drought include dialysis patients, the elderly, pregnant and nursing women, infants, immunocompromised individuals (e.g., chemotherapy and AIDS patients), and persons with preexisting health conditions, such as hypertension and diabetes. This concept has not been sufficiently developed, and therefore is ranked as medium readiness.

C) Indicators with Low Readiness for Implementation for Surveillance

1) Increases in ozone due to climate change. Projections of increases in ozone due to climate change require the application of Global Climate Models and then these estimates need to be downscaled to local areas and are not currently widely available.
2) Pollen Counts. Pollen count data are available through the National Allergy Bureau. Pollen counting stations are manned by volunteers and the spatial distribution of stations is sparse.
3) Injuries/mortality from extreme weather events. There is no coordinated system for reporting. Data is collected by the Red Cross and other disaster organizations and reports often rely on media.
4) Increased respiratory disease due to changes in air pollution and pollens. Requires modeling, downscaling, and application of exposure/response formulas; these analytical strategies are under development.
5) Vulnerability to Flooding. The Federal Emergency Management Agency has not completed converting all flood plain maps to digital format and has not adjusted flood risk for climate change projections.

V Recommendations

- Several environmental health indicators for climate change are at a high state of readiness for surveillance. Many of them, such as heat, extreme weather events, and wildfires are already being tracked by federal agencies such as NOAA/NASA, but definitions should be standardized and surveillance data should be available in one location.
- Excess morbidity/mortality from extreme heat and heat and sea-level rise vulnerability be tracked by the NEPHTP.
- Funding should continue in order to promote the development, pilot testing, and compilation of state and national data for climate change indicators.
- Maintenance of surveillance systems for the incidence of Harmful Algae Blooms and their human health effects should be a high priority for NOAA and CDC.
- Continued research should be funded on how environmental infectious diseases and foodborne diseases will respond to changing climatic conditions.

- Further development of food and waterborne disease surveillance systems is recommended to reduce underreporting.
- More research should be funded for human exposure assessment for wildfires and factors involved with human vulnerability to drought.
- More modeling and research is necessary to predict increased ozone levels and respiratory illness due to climate change.
- Funding for a robust nationwide pollen monitoring system should be a priority.
- A coordinated system needs to be developed to provide accurate and timely information on deaths and injuries due to extreme weather events.
- Electronic flood plain maps which take into account predicted changes due to future climate variability need to be developed.
- The climate indicators may be more sensitive or more suited to some areas than others. Each state should identify its appropriate local indicators.

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VIII Appendix

Environmental Health Indicators of Climate Change for the United States
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