Climate Change and Human Health: Assessing the Climate Information Gap

Summary, Discussions, and Action Items

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NOAA's National Climatic Data Center
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PANEL SUMMARIES

Climate Products and Perspectives

The Climate Products panel began with a presentation by David Easterling (NCDC), who gave an overview of the suite of weather and climate datasets available through NCDC and the issues and degrees of uncertainty that arise when using these data to address questions related to public health. The primary types of data discussed were in situ (surface observations) and remotely-sensed (radar and satellite). Achieving a complete and accurate (i.e., homogenous) time series of weather and climate information is difficult due to lack of data availability in certain parts of the world as well as the quality and precision of the observations. This can lead to much uncertainty in the trends and patterns revealed by the time series (i.e., are the trends based solely on climate or inaccuracies in the data?). While quality control measures have been established to deal with erroneous or spurious data, there is still much work to be done to fill in the gaps where data are missing and to increase confidence in long-range climate projections. Both of these may be achieved through the integration of model data with the historical observations and the development of ensembles to better quantify the range of acceptable uncertainty. Ensembles may also improve confidence in downscaled climate models, which are becoming more sophisticated (i.e., "earth system" models that incorporate atmospheric chemistry and interactive vegetation and energy fluxes). There is also a need to refine the definition and interpretation of the climate "normal", which is often presented as a 30-year average of weather conditions, but for most applications this metric is not always useful.

The second panel presentation was given by Wassila Thiaw (CPC), who discussed the capacity of CPC in addressing the issues related to climate and human health, particularly in the context of early warning systems. The strength of the CPC is in short-term climate forecasting (from weeks to years) using a suite of large-scale forecast products and integrating them with time series of major modes of atmospheric circulation and variability (e.g., El Nino-Southern Oscillation, North Atlantic Oscillation, etc.). The monitoring capabilities of the CPC are global and the International Forecast Desks are actively building capacity in weather and climate in developing countries through interagency and international cooperation to help mitigate the impacts of extreme/hazardous weather and climate events. A "success story" involving collaboration with UMD following the cholera outbreaks in Senegal in 2005 illustrates the CPC's capacity in assisting the health community with responding to climate-driven health concerns. Ongoing projects with relevance to the public health community is NOAA's Climate Test Bed, which acts as a vehicle to transfer information between the research and operational communities to create more sophisticated forecast products. Funding opportunities are routinely available to utilize the CTB in advancing the transfer of data, models, and information to operational products within the NOAA community. Another initiative involves the NCEP-CSFR global re-analysis project, which aims to provide a more complete global time series through integration of higher-resolution model data with the observational record. This will provide useful information over data-sparse regions. The CPC is also looking into adopting GIS technologies and integrating extreme events and other variables (e.g., wind, sea ice, sea level) into its forecast products.

The final presentation was given by Peter Robinson (SERCC), who discussed the theory of climate science for application in the public health sector and how to deconstruct the long-term trends in climate and interpret trends in the outcomes of climate change (with a focus on heat waves). The basic concept of climate service involves analysis of weather observations, followed by the summary and

creation of information to meet the needs of the user. However, it is clear that this concept does not operate as a one-way street. To create the most useful products, the user must be fully engaged in the process from the beginning. This may ultimately lead to the development of new observational platforms as the needs for climate information become more sophisticated and complex. The SERCC has the capacity to facilitate this process by providing the necessary data, information, expertise, and is more oriented towards research development (i.e., has less restraints) than other federal agencies. Downscaled climate modeling may be best achieved through collaborations between the model users (theoreticians) and the experimentalists; up to now it has been rare for these two groups to work together on addressing the uncertainty of downscaled models. Though climate change is typically considered only in terms of global rises/falls in temperature, the details of these trends may hold particular importance to the health sector. By uncovering the regional and sub-annual trends in temperature (and precipitation), we can gain additional insight into the underlying physical mechanisms that are driving them, making it possible to establish better mitigation and adaptation strategies. Using North Carolina as an example, the long-term trends in temperature are revealed by looking primarily at nighttime and winter season conditions. The latter may in fact be due to shifts in circulation patterns that bring warm and cold air masses into the region. For this reason, events such as heat waves and cold air outbreaks exhibit "pseudo" randomness.

Comments and Questions

- *Level of uncertainty with climate monitoring equipment.* A large majority of available long term data of climate measurements take place at airports in support of the aviation industry. In this environment, precision for forecasting was not held to a high standard and is discontinuous, often missing a degree or two. Up until the 1980s no conscious effort was made for more precise climatic observations. Currently, this problem has been mitigated with the Climate Reference Network.

- *Commentary on Arctic Ice Caps, Sea Level Rise, and North Atlantic Overturning.* It was highlighted that for the Southeastern US this issue is not on the forefront for climate communities, but rather an issue for emergency management. It was also noted that there have been a number of implications in other areas such as coastal erosion along the Alaskan coast and in particular in the poles where satellites have monitored the significant declines in ice since the 1970s.

- *Elaboration of the CPC's CSFR global forecast re-analysis.* The CSFR is based upon GCMs and data records dating back to 1948 and up to the early 1990s. CSFR is designed to create data that will aid in the understanding of climatic variability, by creating more precise, historical estimates. These estimates are created by combing observations with models in a form of re-analysis.

Federal Health Perspectives

The panel on Federal Health Perspectives of climate information began with a presentation from George Luber (CDC) on the CDC's perspective of climate change and its use of climate information to survey, track, forecast, and provide consultation on public health outcomes. There are a large number of national centers within the CDC organizational framework with interests in climate change. The areas garnering significant interest at the moment are those involving water and food supplies, mental health, and environmental refugees. In addition, much uncertainty remains with regard to climate change and vector-borne disease and this continues to be a high-priority area. Issues related to climate change and its effect on vulnerable populations has also garnered significant interest at CDC. Since more than half

of the global population now lives in cities, it is likely that cities and climate are "co-evolving" in a manner that will create more vulnerable populations (e.g., reliance on air conditioning, exposure to atmospheric pollutants, stresses on health care delivery). There is now a growing appreciation for looking at climate extremes and extreme events; indeed, extremes impact populations more than changes in mean conditions. Lessons learned from the 2003 heat wave in Europe will hopefully result in better communication and coordination between health officials and meteorologists. More generally, there needs to be a developed capacity to respond to extreme events and short-term climate variability (e.g., heavy rainfall and disease associated with ENSO). The Climate Change Program, which began in February 2009, is laying the foundation and framework for this. A number of priority actions were discussed that addressed the role of the CDC in mitigating the effects of climate change. These included establishing the CDC as a credible source for public health information on climate change, tracking environmentally-sensitive diseases, expand modeling capabilities (including downscaling), enhance the science base, identify vulnerable populations, develop partnerships, and broaden the levels of expertise on the health effects of climate change throughout the public health community.

The final panel presentation was delivered by Caroline Dilworth (NIH/NIEHS), who outlined the various climate change activities currently being pursued by NIEHS. One of these activities is participation in the Interagency Working Group on Climate Change and Health, which is tasked with developing a strategic plan for research on the health effects of climate change by coordinating activities across the US government and identifying the appropriate federal resources and agencies that can help. A comprehensive white paper is being developed (still in its initial drafting stages) that provides commentary on the public health perspectives of climate change (i.e., human health consequences, not climate, are the focus). Specifically, the goals of the paper are to identify research needs, quantify the amount of knowledge available, emphasize the wide range of factors and people involved, and identify appropriate resources. Another activity involves the Trans-NIH Working Group on Climate Change and Health, which focuses on the role of NIH in issues related to climate change and human health and developing strategies for supporting research in this area. A portfolio analysis indicated that overall, there is very little research being conducted or funded on the direct effects of climate change on human health. Most of the work involves mechanistic studies where climate effectors are not explicitly addressed. In addition to these activities, the Recovery (stimulus) Act of 2009 is providing NIH with funding opportunities to address issues germane to climate and health. Several projects focused on predicting human health effects of climate change will be funded under the NIH Challenge Grant funding opportunity. Lastly, NIEHS is part of an international consortium aimed at quantifying the population health consequences of key policy choices to reduce GHG emissions. The consortium is planning to submit a report in time for the UN Climate Change Conference in Copenhagen in December 2009.

<u>Comments and Questions</u>

- *Difference between NIEHS & CDC.* NIEHS was identified as a research organization that traditionally has supported basic biomedical research and research activities such as risk communication and research dissemination. The organization is structured such that fundamentals of scientific health such as pathology and intervention tend to be targeted on the individual level. The CDC retains a focus on public, community and population effects; therefore, having a more applied approach then NIEHS.

- *Purpose of ad-hoc interagency working group.* The original purpose of the interagency working group was to establish what is known about climate and health, what research is needed and the priorities of such research needs. It was also noted that though there has been a review, there has

been hesitancy towards prioritizing research needs; instead research needs have been presented in a broad manner.

- *Implications of pesticide use from Climate Change using example of West Nile Outbreak.* During this time, there was increased pesticide use in areas of human exposure particularly in the South where pesticide use is perceived differently and is more accepted than Northern communities. Before this outbreak, pesticide spraying had been focused on communities applying only where it is needed. After this heavy, widespread pesticide use in Southern communities, the CDC found low exposure to communities despite increased spraying.

Federal Agency Perspectives

The panel on Federal Agency Perspectives of climate information began with a discussion lead by Pai-Yei Whung (EPA). She outlined the EPA's commitment to climate change activities, through the newly-formed interagency group on climate change, collaborations with the WHO, a "One Health" approach to addressing climate change outcomes, and the development of successful projects that lead to better decision making, policies, risk assessment, and regulations. Part of the climate change-human health problem involves determining whether existing regulations and guidelines with respect to air and water quality (including sub-surface) need to be re-evaluated in the context of climate change. The EPA has been involved in a variety of projects with ties to health and climate change and it is now time to address the value of these projects with respect to policy and regulation. These include air quality regulations resulting from forest fires, land use management, and drought, as well as water quality regulations targeted at pesticide use (ongoing collaboration with the USDA). Possible ideas for future work and engagement include the development of climate-health indicators, international assessments of the economic costs of air and water related illness, and operational development of early warning health systems. Overall, the work done at EPA demonstrates the importance of partnerships in a field that is truly multidisciplinary.

The next panel presentation was delivered by Daniel Strickman (USDA). He works within the USDA's Agricultural Research Service (ARS), which is the chief scientific research agency of the department that oversees hundreds of projects aimed at solving both complex and "everyday" problems related to agriculture. Beneath the umbrella of the ARS is the Overseas Biological Control Laboratories, which are directed by Dr. Strickman. These laboratories conduct research on biological control agents of invasive species. These include both insects and vegetation, which are driven by climate change. The distribution of these control agents may also be influenced by climate change, which can lead to land management problems, flooding, etc. Other climate-oriented interests within ARS include management of natural resources, crop protection, and modeling of potential disease vectors (e.g., Rift Valley, West Nile). With regards to challenges with using climate data, there is little information available at a scale appropriate to measure microhabitats, or microclimates, although HOBO stations set up for field projects can give some insight. Additionally, it would be useful to determine the most appropriate methods for interpolating between data points as well as taking coarse, regional models and downscaling to a level appropriate for modeling habitat conditions.

The third panel presentation was delivered by Tanya Maslak (USGCRP). She provided an overview of the USGCRP, how and why it was conceived, and how it can be useful to interagency and cross-disciplinary projects that address climate change and human health. The ultimate goal of the USGCRP is

to coordinate and integrate scientific research, with a focus on the environmental sciences, on global variability and change across a number of governmental agencies. The USGCRP supports a number of synthesis and assessment products, one of which is the effects of global change on human health and the welfare of human systems. Recent recommendations by the National Research Council suggest further development in understanding the human impacts of climate change, particularly as it relates to the increasing number and scope of vulnerable populations. There also exists a strong need for additional agency representation, especially at the regional and local levels (e.g., oceans, state health officials, EPA, etc.), as well as improved stakeholder engagement to make the research and development process more user-driven. The USGCRP is in a unique position to act as a coordinating body in facilitating many of the activities that arise from this workshop.

Juli Trtanj (NOAA) provided an overview of activities with the NOAA-Oceans and Human Health Initiative, which is charged with pulling together NOAA resources to better understand and combat human and animal health issues pertaining to coastal development, biodiversity of marine ecosystems, and changes in water quality and quantity for ecosystem health, recreational uses, and sanitation (among others). OHHI functions at the intersection of human health, animal health, and coastal ecosystem health. It coordinates various NOAA Centers of Excellence, advisory panels, grants, contracts, scholarships, and public outreach. It is the nation's lead ocean agency with the goal of developing early warning systems through cross-disciplinary and interagency cooperation to optimize the health benefits of oceanic resources. Some of the success stories from various Centers of Excellence were discussed. NOAA as a whole has been active in the area of climate and human health since the late 1990s; many success stories and ongoing projects exists, but there is much work to do. One area of current interest is in Cholera early warning. Future partnerships formed with the WHO and CDC will help jump start these and other programs. The One Health approach is extremely inviting and useful, but will require substantial coordination and collaboration.

The final panel presentation was delivered by Lori Schwacke (NOAA-Center of Excellence, Hollings Marine Laboratory). The research focus of the HML is on the development of analytical methods, diagnostic tools, and models for understanding and predicting the health effects of algal toxins, chemical contaminants, and pathogens. HML has extensive experience in studying harmful algal blooms, which are shown to be sensitive to changes in ocean temperature, as well as the trophic transfer pathways of various pathogens that may pose a health risk to humans. The links between pathogens, algal blooms, and climate at the watershed scale likely require specialized climate information. These data requirements are not fully known yet, but forming partnerships with the climate community can lead to better predictive models when integrated with sophisticated ecosystem models. In general, the connections between climate, marine ecosystems, and human health are a new but important focus of the HML.

<u>Comments and Questions</u>

- *Scaling issues of vector borne diseases (implementation of micro-environment experienced by specific vectors).* Insects seek certain micro-environments dependent on meteorological parameters such as humidity, air temperature etc. Though there is a tremendous amount of research in phenology, there is little research on micro-environments. This is in part due to the inability to harness temperature probes on vectors such as mosquitoes. Future work involving the meteorological influences on microenvironments would be very useful to the field of entomology and its relation to climate change. It was also stressed that the spread of infectious disease is contingent upon socio-economic factors. A prime example is the difference in the pattern of Dengue Fever along the US-Mexico border.

NGO Perspectives

Gino Marinucci (ASTHO) presented on behalf of the NGO Perspectives panel. ASTHO is a national nonprofit organization representing state and territorial health agencies in the United States. The overarching goal of the organization is to formulate and influence sound policy in the health sector as well as assure excellence in state-based public health practices. There are numerous challenges with ascertaining the climate change priority within the state and territorial health agencies due to lack of resources and the different levels at which climate information is used. The original thirteen discussion questions posed by the conference organizers were disseminated to various programs within ASTHO, the results of which were discussed in this presentation. Many of the programs responding seemed interested in gaining the technical expertise to integrate climate data into their health investigations, particularly at the regional and local levels. Having the data in a useable form is also important. Having a better understanding of the variability in extreme events, their long term trends, and issues pertaining to data quality and uncertainty were also priority considerations. Data needs are fairly standard; most are the standard weather observations as well as derived products (heat index), air quality measurements, and groundwater. However, most cite the need to improve spatial and temporal resolution to make the information more applicable at the local level. This is of particular importance in the context of emergency planning and response. Seasonal forecasts and outlooks, however, have been useful for evaluating the potential for vector-borne disease prediction (along with surveillance) and preparedness planning for the hurricane season. With regards to uncertainty, most programs focus on accurate and reliable communication of probabilities without going in to the minutiae of the problems associated with it. A survey of the climate change needs of the various ASTHO partners conducted before the workshop revealed that while state health officials are aware of climate change and are knowledgeable about its impacts on the health sector (e.g., they seem to be aware of what types of health outcomes they should be planning for), they have very limited and basic experience with applying climate data and information to their programs and practices. Raising awareness of this issue and training state health officials on how to use, interpret, and communicate climate information to their clients should be a priority.

<u>Comments and Suggestions</u>

- *Relationship between state climatologists and state health directors.* Suggestions of fostering a relationship between state health directors and climatologists similar to the relationship between climatologists and city, regional planning was noted. Although, state climatologists could directly address climate needs for state health directors, ASTHO representative Gino Marinucci remarked that climate change is too long term of an issue for the majority of public health professionals. Instead, there is a need for a climate change coordinator who can reach beyond the scope of the agency because the existing environmental directors have no successful reach. Overall, a more holistic, cross-cutting public health approach that includes public health educators, climatologists, epidemiologists' are needed in order to successfully implant a climate change health program

Climate Input Needs for the Health Sector

The panel on Climate Input Needs for the Health Sector began with a presentation by David Richardson (UNC School of Public Health). He outlined various climate data needs and considerations in the context of ongoing work with the UNC SPH using a statewide near real-time emergency department

surveillance network (NC DETECT). Though consisting primarily of data from major hospitals in nearly all NC counties, additional data sources from the Poison Control Center, VA hospitals and EMS are becoming integrated into the system. The surveillance system is primarily concerned with detecting the early signs of a disease outbreak, but has also been useful in identifying trends in environmental and occupation injuries and hazards. From an epidemiological perspective, some of the challenges in using historical climate data and information include accounting for missing data, dealing with outliers (usually measurement issues), and accounting for the spatial misalignment of health data and climate data. The latter is of particular importance as most health information is coded at the zip code level, which is much higher resolution than the network of NWS-monitored weather stations. There are a few options available for dealing with missing data. These include available/complete subject analysis (random assumption), single imputation or smoothing, conditional imputation, and model data integration (reanalysis). Accounting for uncertainty in the data requires other approaches, such as the Bayesian approach (weighted scenarios) which has been useful. Short and mid-range forecasts also appear to be useful in epidemiological studies, but have not been adequately tested in this setting.

The second presenter in the panel was James Studnicki (UNCC Public Health Sciences), who provided an overview of NC-CATCH, a large health care data warehouse that is now into its third generation focusing on complex, multidimensional analysis. The structure of the warehouse allows for analysis at the event level, which is useful for studies involving ecological issues, complex systems analysis (non-linearity), and rare/extreme events. Important features of the warehouse include a vast array of data sources, health indicators, comparisons, granularity, longitudinal capabilities, and a number of interface characteristics that allow for expansion of information into a wide range of user networks. The richness and operability of the warehouse, which is currently available for three states (NC, CA, FL), can foster close collaboration with the climate community. Some of the more appealing avenues for collaboration include risk adjustment studies involving climate factors and urban health outcomes related to air quality and temperature.

<u>Comments and Suggestions</u>

- *Expressed need of health data within the field of biometeorology and climate field.* Health data is needed beyond the time scale of weekly time summaries. This comment was followed up with the statement that NC-DETECT has the potential to provide data on the scale of hours. Additionally, there was discussion over the impact of HIPA (Health Information Privacy Act) on data access for climatologists.

- *Difficulty in fine scale precipitation.* Fine scale precipitation patterns have a seasonal aspect that is extremely variable on short periods, scales. It is plausible to get a sense of the precipitation data with radar imagery, but the further away from an observing center there is an abrupt increase in uncertainty

Issues of Scale for Climate Information

Robert Davis (UVA Environmental Sciences) was the first presenter of the panel on Issue of Scale and gave an overview of the problem from the perspective of a bioclimatologist. Using an ongoing study of air quality and respiratory distress in the Shenandoah Valley, he emphasized the importance of considering pollutants and their distribution when data are only available at points sparsely located over a broad, topographically diverse region. Since climate, health, and air quality information are only

available at points, it is difficult to generalize these conditions over broader areas. It is also increasingly difficult to assess the interplay of these variables due to inconsistencies in the data. From the perspective of mitigation strategies for air quality, understanding the physical, mechanistic links between these variables is important and has been under-examined primarily due to issues of scale with the data. Therefore, how one conducts a bioclimatological study – the parameters examined and the questions asked – will be dictated up front by the nature of the data. One example of a bioclimatological study that illustrates these issues is the pattern of heat mortality in rural areas. Nearly all major studies of heat mortality have been conducted in cities where health and climate data are readily available. How to aggregate information from urban areas to rural areas is highly problematic and requires statistical tests with varying levels of confidence. Reanalysis is helpful in some cases, but high-quality observational data continues to limit progress in this area.

Patrick Kinney of Columbia University addressed the issue of scale using his work with The New York Climate and Health Project. In his presentation he illustrated the data limitations that arose when trying to assess the common spatial factors that predict vulnerability to heat mortality (e.g. social, demographic, bio-physical environmental factors). When collecting spatial data, limitations arose with the lack of meteorological stations. Covariates such as remote sensing of surface temperature are useful on the spatial scale, potentially providing information on the scale of meters. But remote sensing is also extremely limited by its temporal resolution, which is available within several days. In contrast to climate data, Kinney found that health and covariate observational data are identified on the magnitude of meters to kilometers. During his presentation, Kinney reinterred important questions about climatic data such as combining remote sensing with observational data, downscaling models either statistical or dynamically, appropriate projection models over the 10-30 year time periods, and the usefulness of daily to seasonal variability output in these models.

<u>Comments and Suggestions</u>

- *Suggestions of using children's study of air pollution instead of emergency room data for allergen research.*

Climate-Health Research Results

In this panel, Patrick Kinney addressed the temporal scale challenges of predicting future health impacts using his research within the New York Climate and Health Project. In this project, several approaches were developed to assess NYC's climate and health. These approaches include creating an integrated modeling system to project future ozone/heat, developing an exposure response functions for temperature, ozone, and PM_{10}, examining alternative greenhouse gas growth scenarios, and finally combining these findings to assess potential mortality risks in the NYC metro area. Kinney illustrated these approaches with the A2 model for 2020, 2050, 2080 and modeled changes in ozone from mean 1 hour maximums to percent ozone related deaths. These approaches illustrate the limitations of models, in particular their inability to capture climate within the next ten years and their inability to capture extremes and significant climate variability. Kinney also addressed the question of the ensembles' ability to capture a range of temporal patterns as well as a range of mean climatology.

David Richardson discussed the ongoing North Carolina Disease Event Tracking and Epidemiologic Collection Tool (NC-DETECT). NC-DETCET is an ongoing emergency department tracking system that uses real time admission data. In North Carolina, NC-DETECT became a statewide mandate for

electronic submission of emergency department data in 2005. Prior to 2005, electronic submission of data was only voluntary and few hospitals took part. Richardson presented the data elements of NC-DETECT that included variables such as city, county, state, zip, vital signs, insurance coverage etc. Ongoing work with the tracking system includes impacts of temperature, rainfall and climatic factors and vector borne diseases. Incorporation of this research can assist risk models to estimate the number of excess emergency department cases in a given county under a specific climatic condition, as well as help identify regions/demographic groups are experiencing the greatest health risk by linking real time climatic and emergency department data.

In his second presentation, James Studnicki discussed the applicability of the NC-CATCH data warehouse to specific situations. In this particular example, Studnicki uses the example of Florida wildfires illustrating how specific situations of surveillance can allow for early detection as well as large scale data detection. NC-CATCH has the capability to make meaningful measurements of data with pattern recognition engines, alert algorithms etc. that are all compatible for incorporation into various warning systems.

Comments and Suggestions

- *Purpose of Climate Models.* The true purpose and precision of a model is confused within the health sector. Models are established to generate a relative "sense" of future data; there are too many uncertainties to draw quality data. Models are forced chaotic systems with differing oscillations patters and significant lack of predictability over the shorter time periods such as the next 10 years.

- *Availability of Climate Data in Coastal Regions.* Though there are still limitations in the space-time attributes of coastal data, particularly when compared to data in continental regions, a number of viable options exist: these include a network of off-shore buoys, ground-based radar (which may extend up to 100 km off-shore, but the resolution decreases), and the North American Regional Reanalysis (NARR).

FEATURES SPEAKERS FOR WORKING LUNCHES

The first keynote presentation was delivered by Deke Arndt, Chief of the Climate Monitoring Branch in the National Climatic Data Center. In this presentation, Deke discussed the climate services available from his climate monitoring branch. Products discussed were State of Climate, Global Hazards, US Climate at a Glance, Global Climate at a Glance, Air Stagnation Index, Heat Stress Index, Drought Monitoring, Climate Extremes Index and North American Climate Extremes Monitoring. Deke also commented on other sectors of applied climatology, suggesting that the health and climate community follow the example of agriculture and energy sectors, which have already established a long dialogue of research/product collaboration, allowing the application of local or aggregate climate data to decision support.

The second keynote presentation was delivered by Kristie Ebi, Executive Director of the Technical Support Unit of Working Group II of the IPCC. In her presentation, she addressed the need to assess the exposure-response relationships of health and climate, estimate the current health burden from climate change, and develop scenario-based modeling to project and adapt to potential health risks. She also highlighted the disconnect between climate and public health research and the need for correct climate understanding to utilize climate data. Other suggestions included the need for studies and risk

assessments on the local, national and international levels and further research in lower income countries. In addition to stressing research needs, Dr. Ebi cited two examples of climate-related health effects in both Mali and Melbourne, Australia. In the example of Melbourne, local droughts in 2009 followed by consecutive record high daytime and nighttime temperatures lead to infrastructure damage, forest fires and over 300 heat related deaths and greater than 2000 health related illnesses. This example illustrates the vulnerability of developed societies whom also have trouble coping with such large anomalies. In the example of Mali, temperatures have already increased by 2 degrees Celsius placing strains on already marginal farmlands. With this temperature increase, subsistence farmers are unable to grow Irish potatoes, the cash crop of the region and money source to fuel their agriculture. Along with this temperature increase, decreases in Mali's rainy season has caused rice (the main food source) to have 100 growing days rather than the traditional 120 days, allowing less micronutrients to be absorbed into the food crop. In addition to these examples, climate change also has the potential to increase diarrheal disease, which already compromises 12 percent of world-wide childhood mortality. This increase can be attributable to temperature increases that encourage growth of Salmonella, Campylobacter and E.Coli, as well as extreme rainfall events which threaten water sanitization. By further exploring these climate and public health vulnerabilities and issues, adequate management of the frequency, intensity and duration of such extreme events can be adapted.

INTERNATIONAL APPROACHES

Food Security. Climate change/variability stresses food security in many developing countries. A specific example from this workshop is Mali, whose number of potential growing days has dropped from 120 days to 100 days. This decrease has devastating effects for the nutrients of crops which have less time to absorb micro-nutrients from the soil and also increases their susceptibility to fungus and disease by stressing them.

Climate impacts on Infectious Disease. Pilot projects with UMD and CPC have illustrated climate's impact on infectious disease. For instance, in Sengal studies illustrate that cholera reached maximum towards the end of the rainy season. Further understanding could allow for early warning systems for infectious disease outbreaks influenced by weather parameters. Establishment of climatic thresholds for the distribution of vectors could also improve early warning systems and infectious disease outbreaks.

Lost of economic revenues in agriculture communities. In the example of Mali, warming conditions have lead to the inability of locals to grow and sell Irish potatoes their main source of economic revenue.

Expansion of weather and climate information to other areas of the world. CPC is currently focusing on this in Africa, South Asia and South America.

Environmental Refugees. Established the need to address potential Environmental Refugees, which will suffer the most health consequences from changing climate. Creating risk assessments of these countries affected by environmental refugees, these risk assessments should include climatic data.

ACTION ITEMS

Following the final workshop discussion, the planning committee drafted the following action items (with voluntary input from various participants):

1. Pilot projects and exploratory case studies
    - Spatial heterogeneity in exposure-response outcomes to heat stress
        - Regions of interest where we currently have access to fine-scale health data: North Carolina, Florida, New York City
        - Principal investigators: Peter Robinson, Robert Davis, Patrick Kinney, David Richardson, James Studnicki
    - Precipitation, sea-surface temperatures, and coastal ecosystem response
        - Focus on water and vector-borne diseases
        - Regions of interest: Florida and others along the US east coast
        - Principal investigators: Juli Trtanj and Lori Schwacke

2. Establishment of methodology working groups
    - Spatial scale and issues of interpolation, proximity, and climate variable "footprints"
    - Lead members: Chip Konrad, Robert Davis, Patrick Kinney, David Richardson, Peter Robinson
    - Will support the agendas of both pilot project groups where applicable

3. Linkages between the CDC's National Environmental Health Public Health Tracking Network and NCDC climate data indicators
    - Principal investigators: David Easterling, George Luber, Judy Qualters (CDC)