Heat Wave Project

We want to develop new methods to use environmental data to diagnose and predict heat events that are a danger to human health. This environmental information will then be combined with data that represents the built environment (that is, the cityscape) and the vulnerability of people to heat stress. The goal is to combine these three sources of information to develop an optimal, verifiable system for heat wave warnings that can be widely and transparently implemented.

We seek to bridge the fields of public health, meteorology, and climate prediction. We aim to contribute to development of policy and strategies to adapt to extremes of environmental heat and mitigate the public health impact of that heat.

Human Heat-Health Warning Systems

The development of a heat-health warning system requires three basic steps: how do we determine that there is extreme heat, how does that heat influence the local environment, and how do we identify vulnerable populations? This is illustrated in Figure 1.

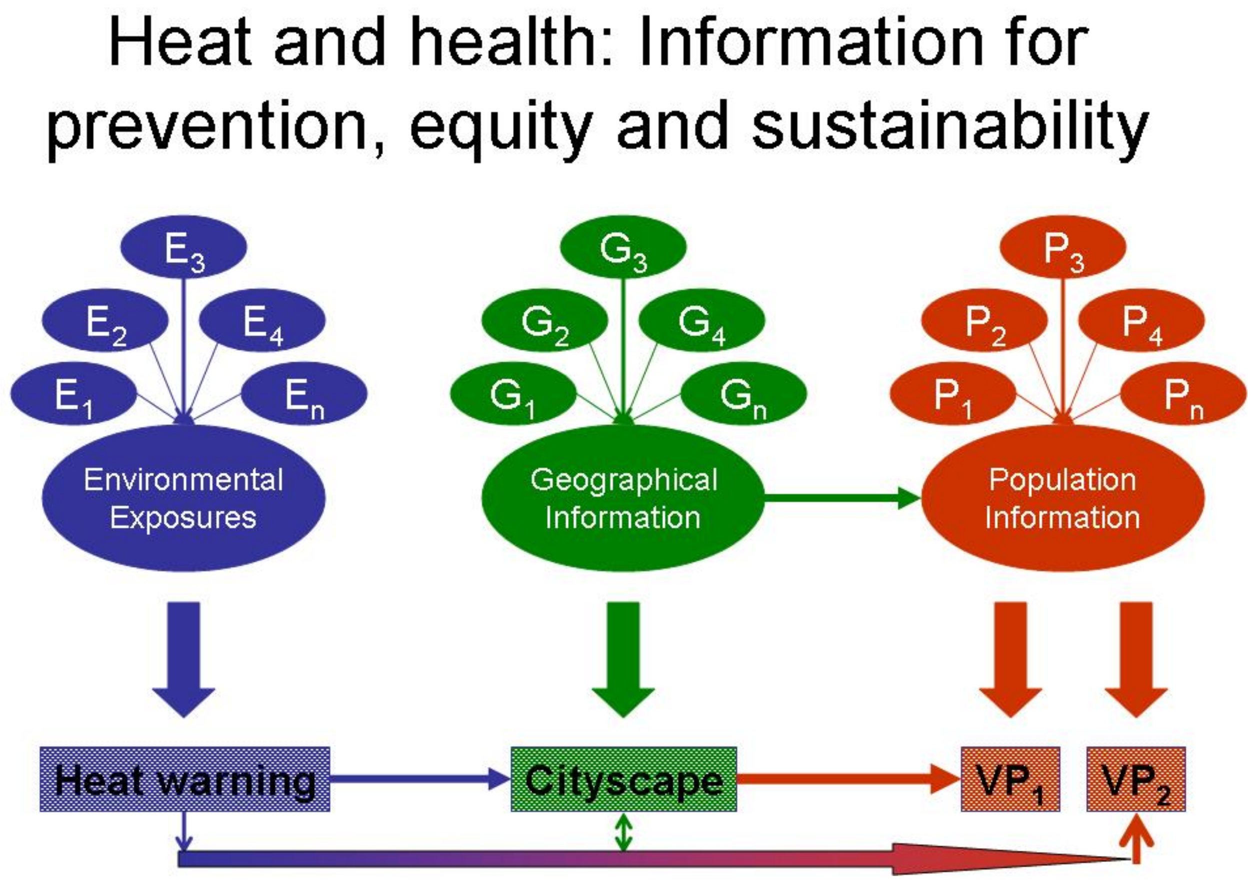

Figure 1: The elements of a human heat-health warning system. See text for description.

Environmental information is represented by the components on the left of the figure. There are numerous environmental parameters (E_n). These parameters are characterized by high variability in time, but also being both well measured and predictable. They may not be fully representative of the environment on the human scale. There are basic parameters such as temperature, humidity and wind which directly affect the heating and cooling of the body. There are also a set of derived parameters such as persistent nighttime minima and a measure of a high-heat episode relative to some background or average. An important distinction that will need to be made is between instantaneous extreme heat and the accumulation of heat in the environment.

In the center of the figure is geographical information, which is also measured by several parameters. These parameters are characterized by being independent of time on the time scale of an intense heat event (that is, constant). Examples of geographical parameters are wooded versus cleared land or land with building or extensive roads. This will be called the cityscape (CS). Quantitative measures of the cityscape are based on the radiative characteristics of the materials at the surface and would include albedo, emissivity, and the ability to hold heat. There can be great complexity of the cityscape.

On the right of the figure is population information, which includes measures, in some aggregate way, of the characteristics of the population. The parameters are directly associated with people, and have tremendous complexity. There is no *a priori* reason for the characteristics of the population to organize into geographical patterns. The purpose of the population information is to assist in identifying people whose welfare is most vulnerable to intense heat.

The arrows on the figure represent an intuitive flow of information through the system as a whole. The environmental data provides a measure of heat, and the ability to determine if that heat is excessive. On one level the intensity of the heat can be determined in an absolute way. For example, the temperature might be two standard deviations removed from a long-term average or an absolute high temperature record. This absolute measure may not directly impact human health. Therefore, information other than temperature is needed to determine the health impact. Often humidity is used, *i.e.* the heat stress index, and experience shows that use of a variety of environmental information improves the usefulness of a human heat-health warning system (see Kalkstein *et al.* (2008) and references therein). One the other hand, experience shows that indicators in one environment, "e.g." humid, are not the best indicators in other environments, "e.g." arid. (see Keim *et al.*, 2007)

There is, implicitly, in the environmental information component of the system an algorithm that combines information from the various geophysical parameters. The product of this algorithm is a measure of extreme heat and an extreme-heat warning flag (EW) is raised. It is useful to define two types of excess heat warning. The first type is an instantaneous measure of excess heat; *i.e.*, it is hot. The second type of warning is based on accumulated heat, for instance, measured by a sustained increase in night time minima.

There is an array of information that is transmitted with the excess heat warning, for example, temperature, humidity, solar irradiance, cloudiness, wind vectors, *etc.* This information can be used to better define the local nature of the excess heat.

The geographical information can be combined with the environmental information to improve the efficacy of the excess heat warning. For example, if the heat event is one with low cloudiness and intense sunshine, the ability of the surface to absorb or reflect solar radiation is important. The Army field manual, for example, warns of a rocky desert environment being more than 30-40 degrees F warmer than the ambient air temperature. Similarly, as shown by Golden et al. (2004), the urban heat island of Phoenix, Arizona may be 10 degrees F higher than the air temperature at the airport. The geographical information identifies potential hot spots.

The ultimate goal of human heat-health warning system is to provide a useful warning to the population. At the human level there are both physiological and sociological parameters that contribute to vulnerable population (VP) groups. This introduces the full complexity of humans. From a physiological perspective it is useful to divide those who are put in risk by heat into two populations. The first are those who are generating heat internally because of physical activity. The second are those vulnerable to high ambient heat. In both cases the heating of the human body is balanced by the ability of the body to cool.

There are both correlated and independent paths by which the geographical and environmental information interacts with the population. As an example, those people who are at risk because of physical exertion are highly sensitive to high temperatures; that is, instantaneous extreme heat. Those more impacted by a sustained inability to cool their bodies are more impacted by accumulated heat. The geographical information that indicates hot spots is potentially important in both situations. The geographical information also carries an independent relation with the population. For example the location of large parks in, perhaps, where to go to find a cool place.

Research, Problem Solving and Openclimate.org

We are investigating all aspects of the heat wave problem. There are a number of take away lessons that are relevant to Openclimate.org.

Climate change will lead to a warming of the average temperature of the Earth's temperature. Regional warming and extreme heat events will be much larger than this average warming. Meehl and Tebaldi (2004) exemplifies the literature that strives to quantify the impact of global warming on extreme heat events.

With regard to climate change problem solving, we discover a number of facts. Heat waves and many of the problems casually linked to climate change already exist. Climate change will amplify these problems, but climate change is not "the cause" of these problems. Because these problems already exist there is generally built capability for addressing these problems. There is a community of researchers who provide foundational information; there are advocates for addressing the problems, and there are providers of services to address the problem. These communities are highly evolved. They are aware of the challenges climate change might bring to their fields.

Generally the most productive routes to address problems such as heat waves are through the existing infrastructure. There are social systems and communication paths set up to inform the vulnerable populations and alert those who provide emergency services. There are strategies for making the population more resilient to extreme heat, such as air conditioning. The existence of this infrastructure along with policy and engineering strategies to address heat waves helps to define the relationship of climate change science to heat waves in the real world.

What becomes apparent from this example is the need to improve the interface of existing community to climate information. Communities need interfaces to archived climate predictions which are consistent with the tools and protocols of their communities. An example is the need for geographical information system interfaces and algorithms for scaling climate predictions to the local built environment. In some cases the ability to configure and perform numerical experiments to evaluate the impact of adaptation strategies is called for. Methods for providing information in the language of these communities are needed. Portals to information including access to tools are needed to reduce the overhead of new participants and to accelerate our ability to solve problems.

Openclimate.org takes the point of view of end-to-end system as highlighted in this example. It seeks to bring together the intellectual resources from different communities and provide an environment in which problem solving is facilitated for existing and future members.