Assessing the Health Impacts of Climate Change
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In many environmental change problems, concern about risk to human health is the key factor turning the torpor of public indifference into a tide for intervention. The climate change debate appears to be following this same pattern. However, two factors make the assessment of human health impacts from climate change very challenging: (i) understanding the role of climate in health, (ii) projecting the future patterns of change in climate and other determinants of public health. It is important to interpret the literature on health impacts of climate change in the broader context of public health issues in a changing global environment. This broader interpretation does not always support the conclusion that intervention to halt or reverse climate change is the best option.

The Links Between Climate and Health
The first challenge in developing an understanding of the health impacts of climate change is detection of links between human health and climate. The influence of climate on human health have been categorized as: direct effects of climatic variables on human physiology, and indirect effects through alterations to range and activity of vectors of disease, and availability of food and safe drinking water.

The detection of health impacts due to climatic extremes is straightforward. Droughts can lead to crop failures, widespread hunger, greater susceptibility to disease, and death. Hurricanes kill coastal dwellers. Heavy snowfalls lead to vigorous snow-clearing by people with frail hearts. These are highly visible events, and interventions necessary to protect human lives are fairly well understood. For example, grain storage and distribution systems and oral rehydration strategies are potent tactics for preventing deaths due to draughts. More spectacularly, mortality due to hurricanes has been slashed by more than 90% through the use of weather satellites for storm tracking and radio broadcasts of warnings in Bangladesh over the past ten years. Finally, in the US, weather forecasters exhort their audience to consider the risks of getting up from their armchairs to shovel snow.

Nevertheless, we face a significant challenge in assessment of health impacts of extreme events in an altered climate regime. The challenge is projecting the frequency and nature of occurrence of extremes in the future. By definition, these are rare events. Thus, detection of trends in empirical data is based on a small number of observations. Furthermore, extreme climate events involve processes which are too small to be represented in Global Circulation Models (GCMs). Unfortunately, even with high resolution regional models, long simulation periods are needed in order to observe trends in occurrence of extreme events. Such simulations represent a significant challenge given current computational technologies. Therefore, at present, climate scientists are unable to offer any concrete insights about how climate change is likely to be reflected in the occurrence of climate extremes in the future.

For many years now, there have been attempts to characterize the direct health impacts of weather on health. The most sophisticated analyses have focused on daily mortality and various climatological indicators. The findings have remained controversial for four reasons:

- Departures from the expected pattern of daily mortality in large metropolitan areas are very small compared to the background variability in mortality. Thus, the detection of changes in mortality due to climatic factors is difficult.
- Where regression models have been developed to explain weather related mortality, there is significant regional heterogeneity in model parameters (and structures). Thus, it is difficult to establish a generalizable cause-effect relationship.
Air pollution and climatic variables are often highly co-linear, making the attribution of health impacts to climate very difficult. While controversial, explicit models of air pollution and weather indicate no statistically significant risks from weather. However, all other factors held constant, weather conditions play a role in emissions of precursors, their concentration and transport in the atmosphere, and rates and paths for atmospheric chemistry. In a sense this is another branch of the indirect health impacts of climate change.

Finally, much of this research has been conducted for urban centers in industrialized nations. In these regions, people spend more than 95% of their time inside buildings with controlled environments. Meanwhile, ambient climatic and pollution measurements are made outdoors. The correspondence of these measurements to actual public exposure is a major short-coming of all assessments.

The extensive work of Kalkstein, and Cifuentes & Lave linking weather and mortality in various US metropolitan areas raises additional questions. Cifuentes and Lave show that in the northeast US mortality is high in cold weather, falling to a minimum (around 20°C in Philadelphia) and rising again above that temperature. In Philadelphia, there are many more days with average temperatures below 20°C than above. A secular warming trend would decrease weather related mortality. On the other hand, Kalkstein has shown that in New York heat-waves take heavy tolls. He also shows that in cities which enjoy higher average temperatures (e.g., Birmingham, Alabama) no heat-wave induced mortality can be detected. These findings can be interpreted in two very different ways. An optimist may point to fewer cold days and higher average temperatures leading to lowered weather related mortality. A pessimist may point to the possibility of more severe and prolonged heat-waves and point to the tragedy of the 700 deaths experienced in Chicago in the summer of 1995.

Studies of the Chicago experience confirm that the people who are ill and socially isolated are at greatest risk. Public health measures aimed at this group have already saved lives in Philadelphia.

The recent research on the physiological underpinnings of health impacts of air pollution point to identifiable mechanisms involving charged particulate matter, smaller than or equal to 2.5 microns in diameter (PM 2.5) as responsible for mortality, and tropospheric ozone, a major cause of morbidity. PM 2.5 are respirable aerosols which interfere with pulmonary function and blood viscosity. If we are to develop process based models of health risks due to climate change, the key question in projection of mortality is how climate change would influence the public's exposure to PM 2.5. The modes of influence would include how changing patterns of temperature and precipitation would influence precursors to PM 2.5, its concentration indoors and outdoors, and patterns of human activity and exposure indoors and outdoors.

Beyond the question of whether the observed health impacts are due to climatic variables or air pollution is the simple observation that much of the local air pollution is due to activities which often also release CO₂ and other radiatively important trace substances (RITS) into the atmosphere. Thus, in 1993 the USEPA and others recognized that there may be "ancillary benefits" of controls on carbon emissions. Analysis of the environmental implications of climate change mitigation strategies revealed that while in many regions benefits would be realized, in some US cities the altered pattern of emissions and perversities of non-linear atmospheric chemistry could lead to increased concentrations of tropospheric ozone.

In China however, where SO₂ emissions from coal combustion are largely uncontrolled, reductions in coal consumption lead to significant health benefits. Thus, for industrialized nations, regional patterns of air pollution and options available for decreasing the emissions of RITS are critical to whether ancillary health benefits are realized.

WHAT ABOUT OTHER FACTORS?

Much of the discussion to this point has been focused on industrial and industrializing nations. Given the isolation of the public from the elements in these regions it is likely that the implications of climate change for the less industrialized nations is much greater. In these regions, simple public health measures such as safe drinking water and sewage systems are largely absent. These conditions lead to widespread prevalence of water-borne and vector-borne diseases.

The second challenge is how to extrapolate from present day observations to projection of impacts from climate change. This is where the context of present day observations is reflected in regionally heterogeneous models linking climate and public health. The reason the context of the observations can be of paramount importance is that in many cases the plausible changes in the context can influ-
ence outcomes more significantly than the projected climate change. As acknowledged in the recent IPCC report, projection of impacts given current exposure modes is relatively straight forward. The challenge lies in the consideration of an evolving context of exposure. However, development of well reasoned and coherent conditions far into the future requires a great deal of discipline. One potent approach to address this challenge has been the development of increasingly sophisticated integrated assessment models. Nevertheless, these models are only as good as the basic scientific information available and serve more to highlight future research needs than to offer an accurate projection of the future health impacts of climate change.

A wonderful illustration of the importance of context can be found in the historic and present day prevalence of malaria. In the climate change literature, it is often argued that global warming will lead to pole-ward migration of the range of mosquitoes capable of transmitting malaria. Given the widespread incidence of malaria in tropical regions, this is a powerful and terrifying prospect. Conditions in the industrialized nations are such that re-emergence of malaria as a pandemic is unlikely. The more reasonable fear is for the risks faced by inhabitants of tropical regions currently spared from the ravages of malaria such as Nairobi.

Evidence for the importance of context can be found in the historic extent of malaria. Between 1780 and 1840 virtually all people living in Ontario, as far north as Ottawa, suffered from a disease called “fever and ague” this was rarely fatal, but was often debilitating. The disease is now recognized as being benign tertian malaria. At the time, the symptoms were successfully controlled by taking Peruvian bark or cinchona now known to contain quinine. Few climatologists would argue that there has been significant regional cooling in Ontario since 1840, so why did the incidence of malaria change from being almost universal to afflicting fewer than one patient per decade? Today, Ontario continues to host three species of anopheline mosquitoes capable of transmitting malaria. However, the large swamps in the south of the province have been drained, other surface waters are well managed, and disease surveillance leads to rapid isolation of patients and severance of the parasite-host cycle essential to further transmission of the disease.

It is clear that public health measures, case management, and landuse play a significant role in determination of the prevalence of malaria than climate. Specific weather events have led to outbreaks with high mortality, but these would be ameliorated in the presence of better health care. Further evidence of the importance of access to health care and basic public health measures comes from recent studies of the prevalence of malaria in villages in Gabon. Where the villages are close to hospitals, there are fewer reported cases. The alarming concurrent trend, is the increasing number of drug resistant malaria strains. I see this as an argument for the need to address malaria through improving public health rather than through pharmacology.

**Coherent Projections Are Challenging**

As noted above, there is a significant challenge in projection of future conditions governing actual incidence of climate related health impacts. Nonetheless, many researchers have focused their efforts on projecting how the “potential prevalence” of various health risks may evolve with climate change. In support of such research we now have laboratory studies characterizing the response of the life-cycle of disease vectors and contagion to different temperature and humidity conditions. Laboratory tests have allowed us to identify the optimal constant temperature for incubation of P. vivex, or the development of mosquito. We now know that if temperatures are higher, the mosquito life-cycle is accelerated by so many days and that the accelerated life-cycle will lead to more blood meals. But surely this is recognizably insufficient to project the future trends in the potential range of malaria. Mosquitoes do not live a blissful life of growth to adulthood, sumptuous blood meals, and procreation. They are part of an ecosystem and preyed upon by various creatures. What does altered climate conditions do to this predatory pressure? What is the consequence of climate change on mosquitoes, their predators, and human exposure? The challenge we face, even in projecting the future potential of malaria, is that we need to consider the whole ecosystem and its response to climate change. Partial analyses of how one component will change are prone to lead us to wrong conclusions.

Consider the issue of intervening to halt climate change as faced in an industrialized country. Such interventions involve control of RITS through measures making fossil fuels expensive or prohibited. In industrialized countries, the response to such measures involves expenditure of capital facilitating: (i) energy conservation by consumers, and (ii) a move by producers away from fuels rich in fossil carbon. The outcome at different timescales is relatively straight-forward to predict. In the long-term, we should all benefit from having reduced climate change. In the short term, there may be an additional bonus of an-
ciliary health benefits due to decreased regional air pollution. However, if in the short-term, China were to expend the same effort in reducing SO₂ and PM 2.5, the health benefits would be an order of magnitude greater.

Now, let us consider the consequence of a similar policy in a less industrialized country. Here, there is inadequate capital to facilitate technology mediated strategies and the response options are more limited. Many of these countries are on the cusp of the transition from traditional biomass fuels to commercial fuels. In these regions the more likely outcome is a move away from commercial fuels and a return to reliance on traditional biomass fuels. This will involve massive expenditures of labor in the collection of fuel (mostly wood), a significant perturbation to patterns of development, denudation of forest resources, and enormous health and environmental sequelae.

CONCLUSION

In motivating the policy related to public health we face a challenge beyond developing a causal link between climate and health. We need to develop an understanding of which path of intervention will offer the most effective strategy for improving public health in the short-term while not compromising the health of future generations.

Imagine there is an equation with health as the dependent variable and climate, landcover, access to safe water, access to sewerage systems, and various socio-economic variables as independent variables. The key question is the relative roles of each of these factors in determination of public health outcome. The experience of industrialized nations points to non-climate factors playing a greater role in determination of disease prevalence. Where intervention to limit climate change leads to retrogression in these primary factors controlling disease prevalence, the appropriate policy is to focus our attention on bringing simple public health measures within reach of the rest of the world, so that even with climate change they are far less susceptible to marginal increases in the potential prevalence of diseases such as malaria, schistosomiasis, dengue, and cholera.

We are urged to favor climate intervention by scholarly papers projecting a 30% rise in the potential for malaria late in the 21st century. I believe we should be facing up to the far more serious challenge of helping the population of the less industrialized nations to: gain access to basic public health, improve patient care, engage in activities which do not expose them to disease vectors, and have institutions which can ameliorate the ravages of climatic extremes.

In the climate change abatement debate, the issue of how to re-circulate carbon taxes highlighted the inefficiency of the current tax system. In the debate surrounding the health impacts of climate change, attention is being drawn to our failure to formulate strategies in pursuit of basic public health goals.

A full version of this essay is in press as an editorial in Climatic Change.

FURTHER READING


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