Penn State Environmental Law Review

Volume 12 | Number 1 Article 7

1-1-2004

# Informed Scenarios of Climate Change in the Mid-Atlantic Region

Brent Yarnal



Recommended Citation

Brent Yarnal, *Informed Scenarios of Climate Change in the Mid-Atlantic Region*, 12 *Penn St. Envtl. L. Rev.* 127 (2004).

# Informed Scenarios of Climate Change in The Mid-Atlantic Region

Brent Yarnal*

## Introduction

The scientific consensus is that future generations will face a changing global climate. Many scientists also agree that more hazardous weather and climate will be an important part of global climate change.[1] Experts think that numerous places will experience more floods, heavy downpours, and severe storms more frequently while other places will suffer more numerous and intense droughts. Some unfortunate places will sustain increased frequencies of both floods and droughts, while other places will experience a decrease in weather and climate hazards. One well-recognized problem is that, at least at present, it is not possible to predict which locations will endure which changes in their hazards.

One thing that scientists do know, however, is that weather and climate disasters have massive impacts on individuals and society.[2] If global climate change makes local climate hazards (i.e., natural hazards associated with weather and climate) more common or more extreme in the future, then the financial and human costs will increase enormously.[3] Yet, despite these concerns, the research community has put relatively little effort into understanding the vulnerability of places to a change in climate hazards.[4]

---

* Department of Geography and Center for Integrated Regional Assessment, The Pennsylvania State University.

1. See e.g., K.E. Trenberth, *The Extreme Weather Events of 1997 and 1998*, 5 CONSEQUENCES 1, 3-15 (1999).

2. K. E. Kunkel, et al., *Temporal Fluctuations in Weather and Climate Extremes that Cause Economic and Human Health Impacts: A Review*, 80 BULL. AM. METEOROLOGICAL SOC'Y 1077 (1999).

3. Francis, D., and H. Hengeveld, 1998. Extreme weather and climate change. Downsview, Ontario: Atmospheric Environment Service, Environment Canada.

4. CLIMATE, CHANGE AND RISK (T. E. Downing, et al., eds 1999).

Climate models and climate downscaling

An important reason for the dearth of place-based research on climate hazards is that three-dimensional global climate models (GCMs) suffer from poor spatial resolution. The models typically employ grid increments of hundreds of kilometers, yet many—if not most—important environmental and socioeconomic processes operate at scales of tens of kilometers or much less.

Until scientists improve GCM resolution and model physics to the point that they are precise enough for projections of climate hazards, it will be necessary to develop ways to work around these limitations. Currently, climate change scientists favor climate downscaling techniques for this purpose.[5] There are two types of climate downscaling: dynamical (sometimes called numerical) and empirical (sometimes called statistical). Dynamical downscaling embeds a regional climate model in a GCM, yielding a spatial resolution of typically 50-100 km. Empirical downscaling statistically relates today's observed surface data to observed large-scale atmospheric conditions. A GCM-based future climate scenario then uses the contemporary statistical relationships to project the details of future climate at resolutions determined by the density of today's surface-observation network.

There are three cautions that go with climate downscaling. First, the results of both numerical and empirical downscaling can only be as good as the GCM data used for the analysis. Because the GCM provides the initial and boundary conditions for the downscaling, inaccurate GCM projections will produce inaccurate downscaled climates. Second, the empirical downscaling approach assumes contemporary relationships between the surface and the atmosphere (e.g., certain storm tracks bring copious precipitation) will continue in a changed climate, which may not be true. Given these difficulties, climate downscaling is at best a stopgap measure until modelers can generate accurate high-resolution GCM projections.

The third caution associated with climate downscaling is that both GCM and downscaled projections typically only provide one future climate state—the average. Both do a poor job of producing the extremes around that average. Yet, it is clear that on a regional and local basis, extreme events (i.e., climate hazards) will have tremendous impacts on ecosystems and people.

With these admonitions in mind, Penn State scientists have been developing "informed" scenarios of climate change. Such scenarios use a deep understanding of the local and regional climate variation over

5. B. Yarnal, et al., *Developments and Prospects in Synoptic Climatology*. 21 INT'L J. CLIMATOLOGY 1923 (2001).

space and time to interpret the mean statistics produced by climate models and climate downscaling. Accordingly, the purpose of this paper is to introduce an "informed" climate model scenario for the Mid-Atlantic Region. The emphasis will be on hydrologic changes resulting from the projected climate change and what those changes mean for climate hazards.

Climate model scenarios for the Mid-Atlantic Region

Four GCMs have helped produce 21st century climate scenarios for the Mid-Atlantic Region.[6] The British Hadley Centre for Climate Prediction ("Hadley Centre") and the Canadian Climate Center ("CCC") provide the transient GCM scenarios used in this article (Figure 1). Despite similarities in their general configurations, different pictures of future climate emerge from these two models. The CCC model shows the Mid-Atlantic Regional climate becoming much hotter over the next century, whereas the Hadley Centre model shows only slight warming. There is no trend in CCC model precipitation over the century, but there are multi-decadal periods that are much wetter or drier than average in the Mid-Atlantic Region. In contrast, the regional climate becomes very wet as the century progresses in the Hadley Centre model scenario. Average annual precipitation values in the last quarter of the 21st century are 20-25 percent higher than present. It is important to note that the CCC model output has less realistic looking year-to-year and decade-to-decade climate variations, whereas the Hadley Centre model output looks more like observed climate variations. Also noteworthy is that, compared to most other GCMs, the CCC model tends to be hotter and drier than average; the Hadley Centre model is nearer the center of the distribution of all models. The Hadley Centre model is more representative of the population of climate change projections than the CCC model.

The precipitation results of the Hadley Centre model are broadly consistent with two earlier climate downscaling studies that focused on precipitation in the region. A dynamical downscaling experiment used the GENESIS I GCM to show a strong increase in annual precipitation, with a greater increase in winter than in summer.[7] A statistical downscaling study applied output from the newer GENESIS II GCM. Investigators found an even larger increase in annual precipitation than in the GENESIS I downscaling, but one that is concentrated in the summer

6. C. J. Polsky, et al., *The Mid-Atlantic Region and Its Climate: Past, Present, and Future*, 11 CLIMATE RESEARCH 161 (2000).

7. G. S. Jenkins & E. J. Barron, *Global Climate Model and Coupled Regional Climate Model Simulations Over the Eastern United States: GENESIS and RegCM2 Simulations*, 15 GLOBAL AND PLANETARY CHANGE 3 (1997).

months.[8]

Consensus Climate Scenario

A consensus of the four climate model scenarios suggests that the Mid-Atlantic Region will become warmer and wetter in the next 100 years. What will such a change mean for the region's hydrology? Neff and colleagues found increases over today's stream flow with the warm, wet Hadley Centre model, but decreases with the hotter, drier CCC model.[9] Both model scenarios shift the season of peak runoff from today's peak in early spring to sometime in winter because, in a warmer climate, today's springtime snowmelt takes place earlier in the year. In addition, more wintertime precipitation falls as rain and is, therefore, immediately available to the stream. It is important to note that the models provide no direct evidence that the region will experience more or fewer floods in the future.

Nevertheless, the historical record suggests that most very wet years in the region are associated with floods, whereas dry years are not. For example, 1996 was the wettest year ever experienced in more than a century of record keeping in the Susquehanna River Basin (the largest river basin in the Mid-Atlantic Region). Averaged over the basin, the total precipitation was 56 inches, as compared to the 40-inch mean of the 1961-1990 base period. Thus, 1996 was 39 percent wetter than the modern average. When compared to the basin-wide average precipitation for the entire period of record going back to 1895, 1996 was an astounding 44 percent wetter.

Devastating floods accompanied the excessive moisture of 1996.[10] Five floods—the January 1996 basin-wide flood, the June Adams County flood, the July floods across western and central Pennsylvania, the September flash floods resulting from the passage of Tropical Depression Fran, and the November flood in Tioga County—resulted in presidential disaster declarations in all or portions of the basin. These were not the only floods in the basin.

As noted earlier, the consensus climate-model scenarios for the late 21st Century suggest significantly increased precipitation over the Mid-Atlantic Region, including the Susquehanna River Basin. Although it

---

8. R. G. Crane & B. C. Hewitson, *Doubled CO2 Precipitation Changes for the Susquehanna Basin: Down-scaling From the GENESIS General Circulation Model*, 18 INT'L J. CLIMATOLOGY 65 (1998).

9. R. H. Neff, et al., *Impacts of Climate Variation and Change on Mid-Atlantic Region Hydrology and Water Resources*, 11 CLIMATE RESEARCH 207 (2000).

10. See B. Yarnal, et al., *The Flood of '96 and Its Socioeconomic Impacts in the Susquehanna River Basin*, 33 J. AM. WATER RESOURCE ASSOC. 1299 (1997); *and* B. Yarnal, et al., *Severe Convective Storms, Flash Floods, and Global Warming in Pennsylvania*, 54 WEATHER 19.

may be an exaggeration to say that the future average climate and hydrology of the area will be like 1996, it is reasonable to suggest that the conditions experienced in 1996 could occur more frequently in the next one hundred years. For example, Figure 1 shows five distinct years with precipitation totals comparable to 1996 in the last twenty-five years of the next century. At the very least, the range of storms and flood types experienced in 1996 suggests some of the climate extremes that could plague the future Mid-Atlantic Region.

Conclusions

There are reasons to believe that floods will be more frequent in the future Mid-Atlantic Region. Climate model scenarios suggest that climate change could bring wetter conditions to the region. Lending credence to these scenarios, long-term observations of regional climate and hydrology show an increase in overall wetness, intense rainfall events, and stream flow.[11] Thus, observations are consistent with the climate-model scenarios and portray an ever-wetter region. There is also a documented relationship between increasing precipitation and increasing flood damages in the region.[12] These conclusions illustrate three ways that future flood damage might occur.

First, the warmer, wetter lower atmosphere associated with climate change almost certainly will increase the frequency of summertime storms, such as those that raked Pennsylvania in summer 1996. This source of flash flooding should become more common in the future.

Second, the warmer, wetter lower atmosphere associated with climate change might increase the likelihood of increased snowfall and of intense rainfall events in mid-winter. Thus, massive rain-on-snow floods like the January 1996 flood could become more frequent in the future.

Third, the warmer, wetter lower atmosphere associated with climate change might increase the frequency of tropical cyclones in the future, but this topic is a source of intense research and debate.[13] It is uncertain whether climate change will increase the threat of tropical systems passing over the region. However, it is clear from the impacts of, among others, Agnes in 1972, Fran in 1976, and Floyd in 2000 that the Mid-Atlantic Region is highly vulnerable to the floods instigated by tropical

---

11. T. Karl, et al., *Indices of climate change for the United States*, 77 BULL. AM. METEOROLOGICAL SOC'Y 279 (1996);, H. F. Lins & J. R. Slack, *Streamflow trends in the United States*, 26 GEOPHYS. RES. LETTS. 227 (1999).

12. R. A. Pielke, Jr., & M. W. Downton, *U.S. Trends in Streamflow and Precipitation: Using Societal Impact Data to Address an Apparent Paradox*, 80 BULL. AM. METEOROLOGICAL SOC'Y 1435 (1999).

13. See e.g. A. Henderson-Sellers, et al., *Tropical Cyclones and Global Climate Change: A Post-IPCC Assessment*, 79 BULL. AM. METEOROLOGICAL SOC'Y 19 (1999).

systems.

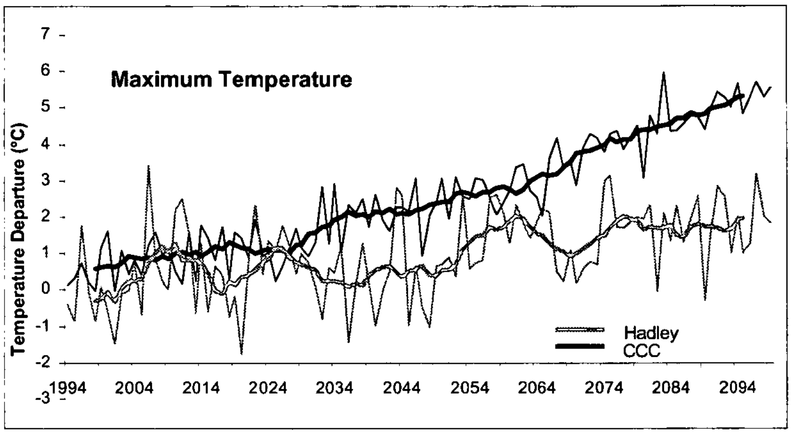
With or without a change in climate, society is becoming increasingly vulnerable to the impacts of floods because of changing human processes.[14] Clearly, to reduce deaths and damages, decision-makers must come to grips with both the climatic and human dimensions of the flood problem and must use this knowledge to reduce vulnerability. Pielke identifies three criteria for mobilizing decision-makers: (1) establish the threat; (2) show that potential responses have a high likelihood of success; and (3) demonstrate that policy options do not impose excessive costs or changes.[15] The regional climate hazard scenarios developed here satisfy the first criterion, showing that the threat of more frequent future flood disaster is likely and thereby paving the way for implementation of the second and third criteria.

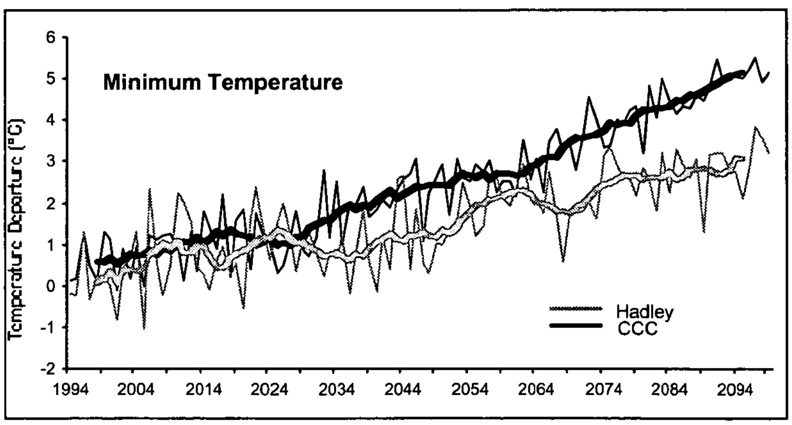
14. R. A. Pielke, Jr., & M. W. Downton, *Precipitation and Damaging Floods: Trends in the United States, 1932-1997,* 13 J. CLIMATE 3625 (2000).

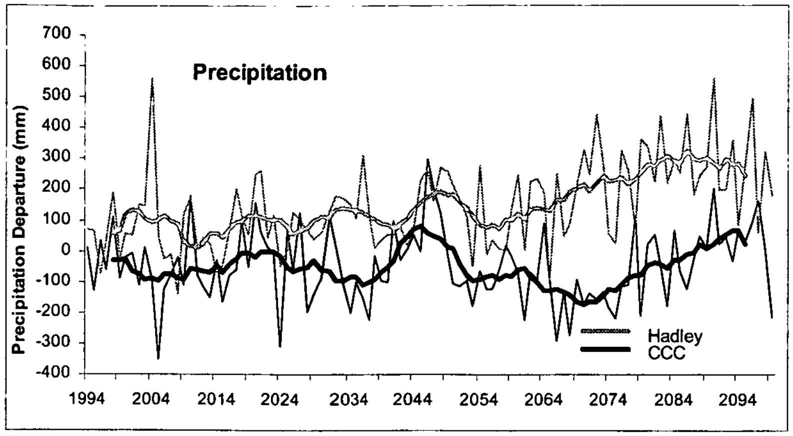
15. R. A. Pielke, Jr., *Nine Fallacies of Floods,* 42 CLIMATIC CHANGE 413 (1999)

Figure 1

Top: Hadley Centre and Canadian Climate Centre model departures from the 1960-1989 observed base period averaged over the Mid-Atlantic Region for mean annual maximum temperature (°C). The departures are nine-year running means. Middle: as in top panel, but for mean annual minimum temperature (°C). Bottom: as in top panel, but for mean annual precipitation total (mm).




Precipitation
Precipitation Departure (mm)
700
600
500
400
300
200
100
0
-100
-200
-300
-400
1994
2004
2014
2024
2034
2044
2054
2064
2074
2084
2094
Hadley
CCC