Climate change scenarios for the New York City Watershed

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Abstract

Global climate change has become a reality. Changes in temperature, precipitation, sea level, droughts and floods present a threat everywhere but coastal cities are particulary vulnerable. In New York City for example, any area below six feet above sea level maybe vulnerable to flooding, including most of the lower Manhattan shoreline, coastal and island areas of Jamaica Bay, much of downtown Hoboken and Jersey City and south shore beaches in Staten Island and the Rockaways (Gornitz et al, 2001).

The research described in this paper is an investigation of climate scenarios using different GCMs and greenhouse gas emissions scenario for New York City and New York City watershed region.

INTRODUCTION

Global climate change refers to a change in the weather conditions such as changes in temperature, precipitation, sea level and wind pattern. Global climate change and global warming are controversial issues but there are undeniable evidence that the Earth's weather is going through changes. Observational data indicate that precipitation is increasing globally, sea level is rising, extreme events are occurring more often, glaciers are retreating and snow cover extend is decreasing. The Intergovernmental Panel on Climate Change (IPCC), a group established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) reports that the average surface temperature of the earth has increased during the twentieth century by about 0.6° ± 0.2°C. The three warmest years on record have all occurred since 1998, the hottest 22 years on record occurred since 1980 and 2005 was the hottest on record. Diurnal temperature range in many parts of the world is decreasing due to an increase of the minimum temperature by nearly twice the rate of maximum temperatures. Increases in daily minimum temperatures are lengthening the freeze-free season in most mid- and high latitude regions[1].

The main cause of global climate change is the increase of greenhouse gases in

[1] http://ccir.ciesin.columbia.edu/nyc/

the atmosphere. Human activities including industrial processes, fossil fuel combustion and land use changes such as deforestation, are the processes primarily responsible for the increase of carbon dioxide and other greenhouse gases.

In order to make long-range climate prediction and to understand how the climate will evolve, scientists are using General Circulation Models. General Circulation Models or GCMs are computer-run, mathematical formulations which include global representations of the atmosphere, oceans, land surface and their interactions. These models are used to replicate the known features of the climate. Proper modeling requires incorporation of the best possible representation of all the important processes and feedbacks in the climate system.

What are the models predicting for the future? What are the regional implications for a critical metropolitan area? The research described in this paper is an investigation of climate scenarios using different GCMs and greenhouse gas emissions scenario for New York City and New York City watershed region.

STUDY AREA

The study area for this project is New York City and New York City watershed. The climate of the New York City region is relatively humid temperate continental with an average annual temperature of 52º F (11º C) and an average annual precipitation of approximately 44 inches (~1100mm). New York City has close to 600 miles of coastline and four out of the five boroughs are situated on islands, making climate change and sea-level rise a serious threat,

In July 2001, the Columbia Earth Institute released Climate Change and a Global City, an assessment of all the climate changes currently anticipated for the "Metropolitan East Coast Region" (MEC). According to Climate Change and the Global City, temperatures in the MEC Region have risen by perhaps two degrees Fahrenheit since 1900. At the same time, overall annual precipitation in the region has increased by about one inch. "However," the report continues, "snow falling on the region has diminished in recent decades, due to a combination of the warmer winter temperatures . . . and a slight decline of precipitation in the winter". According to the same report, "sea level has risen 0.09 — 0.15 inches per year . . . over the last 100 years"—and "about half the observed rise . . . is related to the warming trend of the 20th century". Instrumental records of precipitation on land show an increase of 0.5 to 1% per decade in much of the Northern Hemisphere mid- and high latitudes. In contrast, over much of the sub-tropical land areas rainfall decreased during the twentieth century.

"The annual mean temperature of the New York Metropolitan Region has risen at a rate of 0.252º F/decade (0.14º C/decade) over the course of the last century". Due to greater climatic vulnerability, droughts and floods have become more severe and the sea level rise is increasing at a rate of 1.1 in/decade threatening the sewer system and wastewater treatment plants in costal locations." Changing patterns of precipitation will affect water supply and can also affect water quality through greater phosphorus loading and eutrophication. Higher temperatures will affect water supply through increased evapotranspiration and at the same time may increase sprinkling, cooling and instream demands for water. More intense rainfall may increase turbidity in the watershed regions and result in combined sewer overflow events in urban areas, leading to poorer water quality in the upland and coastal waters respectively. Earlier snowmelt maybe alters the annual cycle of reservoir levels."

Future emission scenarios were developed for NYC area and three possible scenarios were selected. Based on historical and current performance of the models, five models were selected for this research.

DATA SETS AND METHODS

To make a range of projections for each climate variable scientists use several models in combination with different emissions and development scenarios. For this project, from a subset of twenty-two models from the IPCC Data Portal at Lawrence Livermore Laboratory, five models have been selected: The models selected are:

- GFDL CM2.1 (Geophysical Fluid Dynamics Laboratory)
- GISS ModelE (NASA/Goddard Institute for Space Studies)
- MPI ECHAM5 (Max Planck Institute)
- NCAR CCSM3.0 (National Center for Atmospheric Research)
- UKMO HadCM3 (United Kingdom Meteorological Office)

The data is global and in binary format so manipulation is required to work with it in Excel. I used The Grid Analysis and Display System (GrADS) software to select from the global data set the region of interest and a Fortran compiler to convert the data into ASCII files.

In order to be able to predict the future climate, greenhouse gases concentration must be taken into account. Greenhouse gases concentration scenarios were presented by IPCC in a Special Report on Emissions Scenario (IPCC, 2000) and they are created along two axes: 1) economic growth vs. environmental focus and 2) globalization vs. regionalization.

- The A family of scenarios assumes that the future Earth will have an economic growth focus;
- The B family of scenarios assumes that the future Earth will have an environmental focus;
- The 1 family of scenarios assumes that the future will proceed towards a more globalized world;
- The 2 family of scenarios assumes that development will be more regional in nature; (IPCC,2000)

For this research the selected greenhouse gas scenarios were:

- B1 (considered low)
- A1B (considered intermediate)
- A2 (considered moderately high)

In order to develop and investigate the necessary scenarios, the first step was to downscale spatially the GCM data. The watershed region is defined as 40.5° N to 42.5° N and 75.5° W to 73.5° W. The midpoint of the region is used as the center for a search radius large enough to include the watershed region and to omit regions with a different climate regime. The next step was to use GrADS to extract from the global data set only the region of interest and the Fortran compiler to convert the data. Once the data was ready to manipulate, I used Excel to create plots of global and regional temperature, precipitation and sea level rise.

ANALYSIS

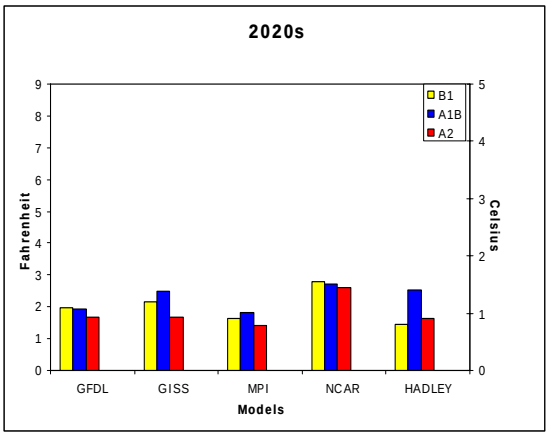
The results underscore the fact that increases in greenhouse gas concentration will continue to influence the earth's climate determining changes in temperature,

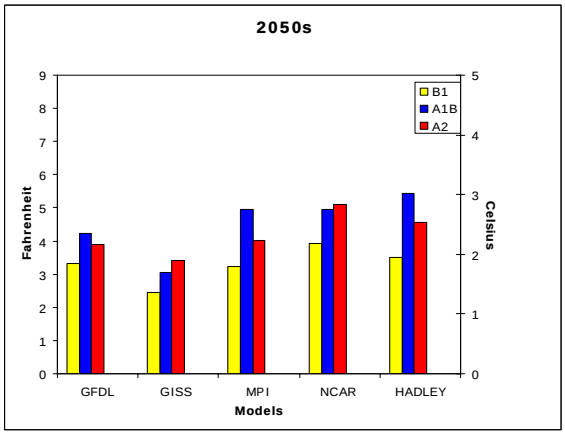
precipitation and sea level.

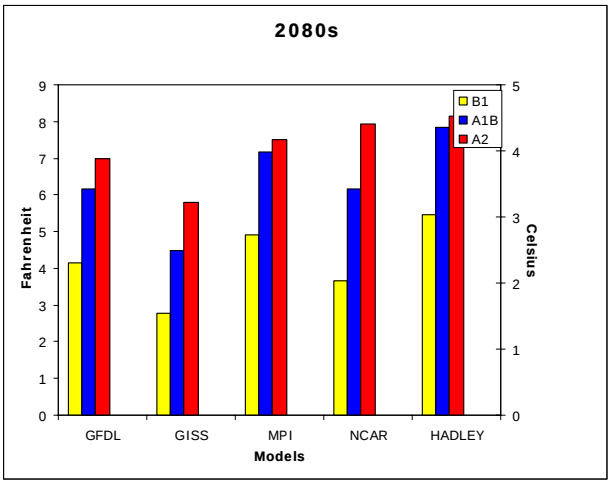
- **Temperature**

The figures presented below show projected changes in temperature for the NYC Watershed Region for the 2020s, 2050s and 2080s relative to the 1970-1999 base period. As shown in the graphs below, these models project by the 2050s the temperature will increase by up to 6ºF for a intermitent greenhouse gases emissions (A1B) and an increase of 8.15ºF by the 2080s with a moderately high greenhouse gases emissions (A2). The smaller increase in greenhouse gases (B1) leads to smaller temperature changes. The seasonal results show similar amounts of warming during summer and winter.

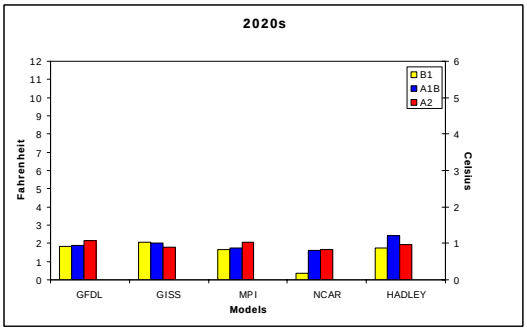
Modeled annual temperature changes for the NYC watershed region relative to the 1980s

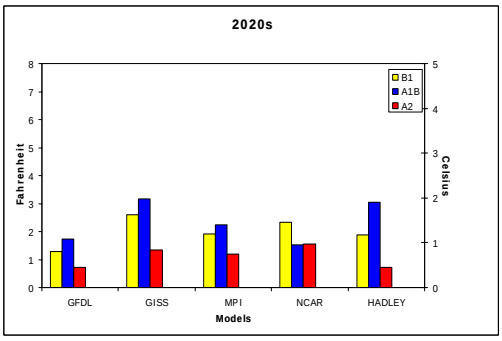


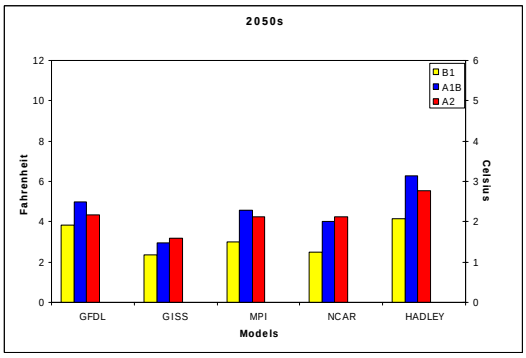


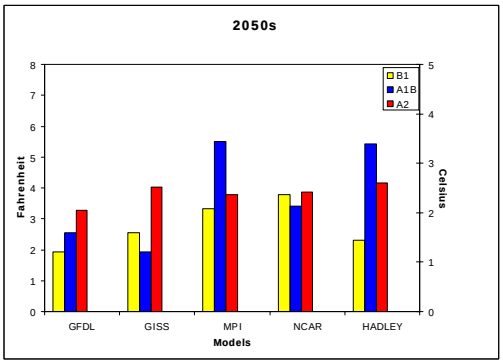


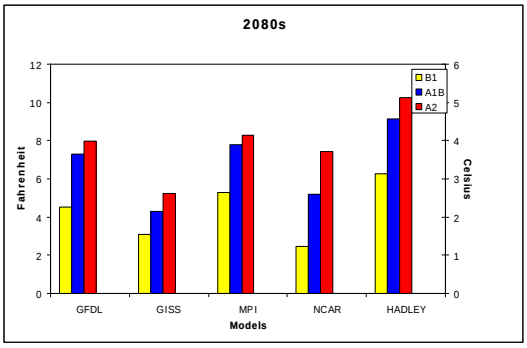
Modeled seasonal (JJA) temperature changes for the NYC watershed region	Modeled seasonal (DJF) temperature changes for the NYC watershed region

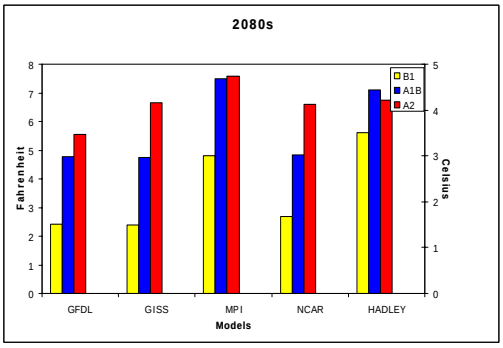








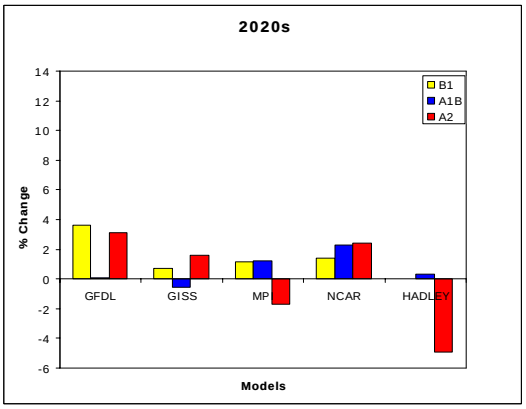


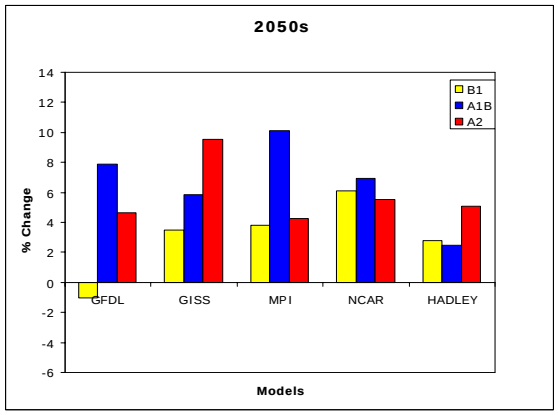


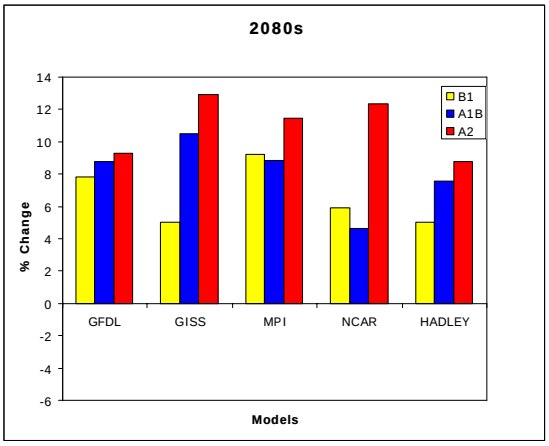
- **Precipitation**

The downscaled annual precipitation scenario results are shown below. Rainfall increases through time and with the amount of greenhouse gas forcing. By the 2050s the amount of precipitation will increase by up to 9.57 percent and by the 2080s by up to 12.9 percent.

Modeled annual precipitation changes for the NYC watershed region relative to the 1980s

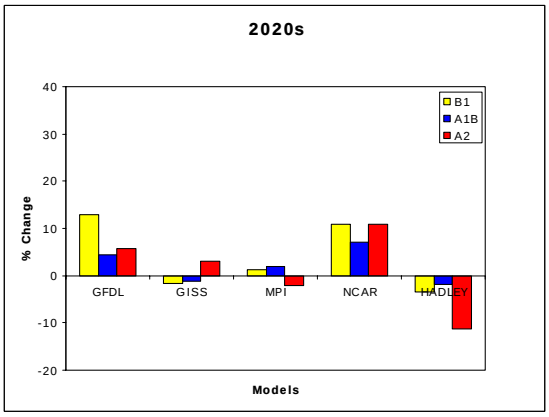


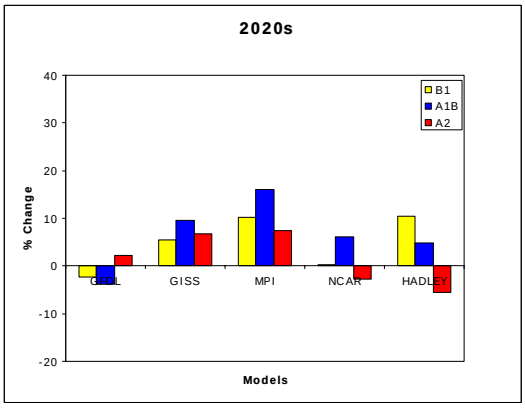


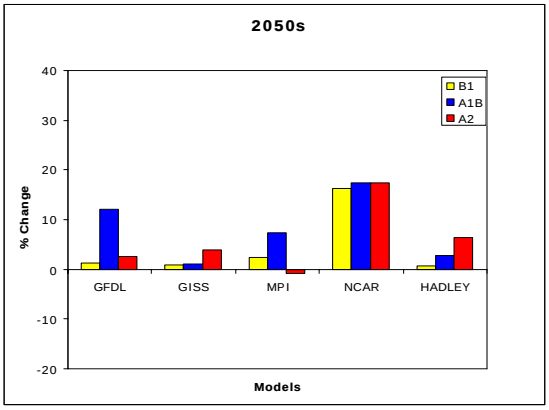


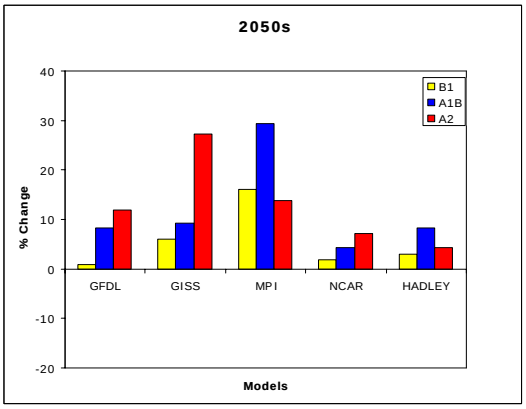
A large increase in the amount of precipitation is projected for the winter season (December-January-February). GISS modelE and MPI Echam project for the winter season an increase in precipitation of between 25-30 percent for the 2050s and over 32 percent increase for the 2080s . Beside NCAR which projects an increase in precipitation of 17.4 percent for the 2050s and 26 percent for the 2080s, the other models projections for summer are smaller. Further investigations that include actvity at sub-seasonal timescales, drought and heavy rainfall frecquency are necessary but not part of this research.

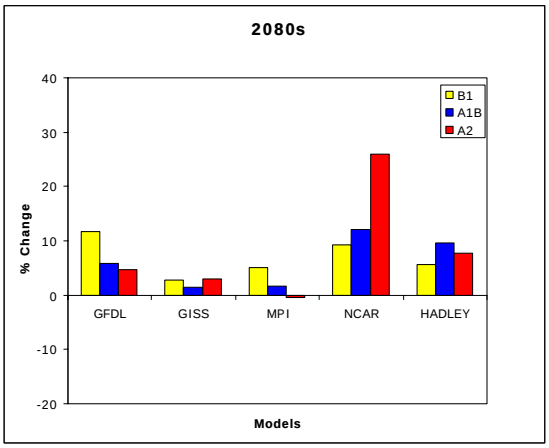
Modeled seasonal (JJA) precipitation changes for the NYC watershed region	Modeled seasonal (DJF) precipitation changes for the NYC watershed region

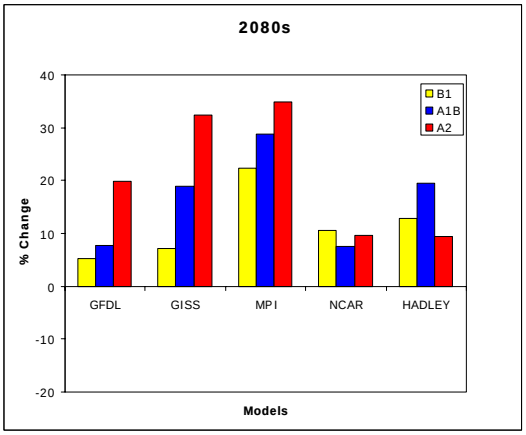






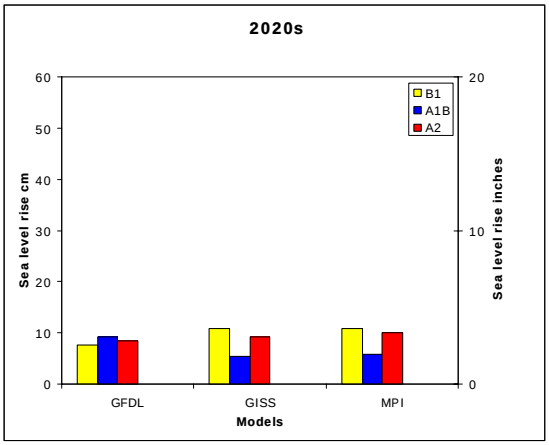


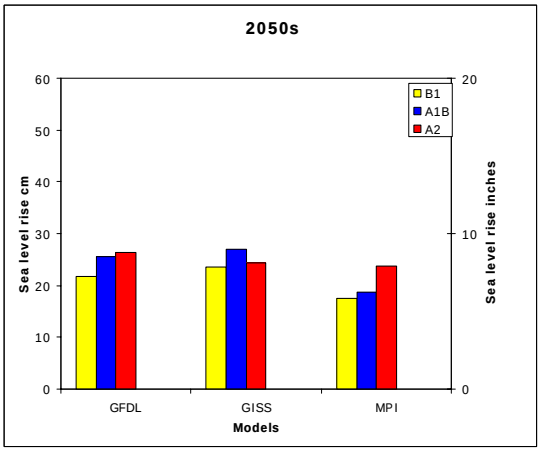


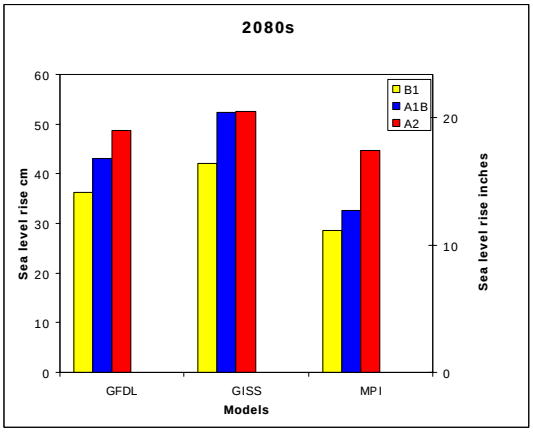


- **Sea level rise**

For sea level rise I have used only data from 3 GCMs namely GISS modelE, MPI Echam and Hadley. All 3 GCMs projected an increase in sea level of up to 4 in for the 2020s, 7 to 10.5 in for the 2050s and more than 20 in for the 2080s. Among these 3 models, Hadley projected the smallest sea level increase and MPI Echam the largest.







Conclusions

Climate change is expected to continue and accelerate in the coming years. Regional climate scenarios based on a range of emissions scenarios and recent climate model simulations are an important tool in assesing climate risks.

All the model results support the hypothesis that increasing greenhouse gases will alter the climate significantly. Warming, precipitation, and sea level rise generally increase with the amount of greenhouse gas forcing. Although all the model results show more similarities than differences, the NASA GISS Model shows considerably more moderate results than the other models. Because climate change is expected to accelerate, and significant uncertainties remain about the details of regional changes, regional climate

change scenario work should play an important role in future climate research.

Acknowledgments

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