Role of precipitation vs temperature in controlling climate change impacts on water resources

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Table of Contents

Table of Figure

Abstract

Recent years have witnessed an increase in global average air temperatures as well as ocean temperatures, as documented by the Intergovernmental Panel on Climate Change (IPCC). The rise in temperature is considered irrefutable evidence of climate change, and this has already started to have serious consequences for water resources and will have even more dire consequences in the future. Compounding these consequences are population growth, land-use changes and urbanization, increasing demands for water and energy, rising standards of living, changing dietary habits, changing agricultural practices, increasing industrial activities, increased pollution, and changing economic activities. All these will likely have adverse effects on water resources. This report discusses role of precipitation vs temperature in controlling climate change impacts on water resources.

Chapter 1

1. Introduction

Climate is the average weather in a given area over a longer period of time. A description of a climate includes information on, e.g., the average temperature in different seasons, rainfall, and sunshine. Also, a description of the (chance of) extremes is often included.

Climate change is any systematic change in the long-term statistics of climate variables such as temperature, precipitation, pressure, or wind sustained over several decades or longer. Climate change can be due to natural external forcing's (changes in solar emission or changes in the earth's orbit, natural internal processes of the climate system) or it can be human induced.

The classical period used for describing a climate is 30 years, as defined by the World Meteorological Organization (WMO). Figure (1)

Figure 1 climate change

Actually, water resources are arguably the most important domain to be considered in a climate change impact assessment study. This importance stems from the fact that climate change has direct impacts on the availability, timing and variability of the water supply and demand, and is also related to the significant consequences of these impacts on many sectors of our society. Water is used for human consumption, industrial purposes, irrigation, power production, navigation, recreation and waste disposal, as well as for the maintenance of healthy aquatic ecosystems.

Its availability and the occurrence of extreme events like floods and droughts condition the location of urban, industrial and agriculture areas, power generation plants and trading centers.

Recently documented activities contributing to climate change can be a major challenge to the availability of freshwater quantity (too much or too less) or quality. As shown in Figure (2)

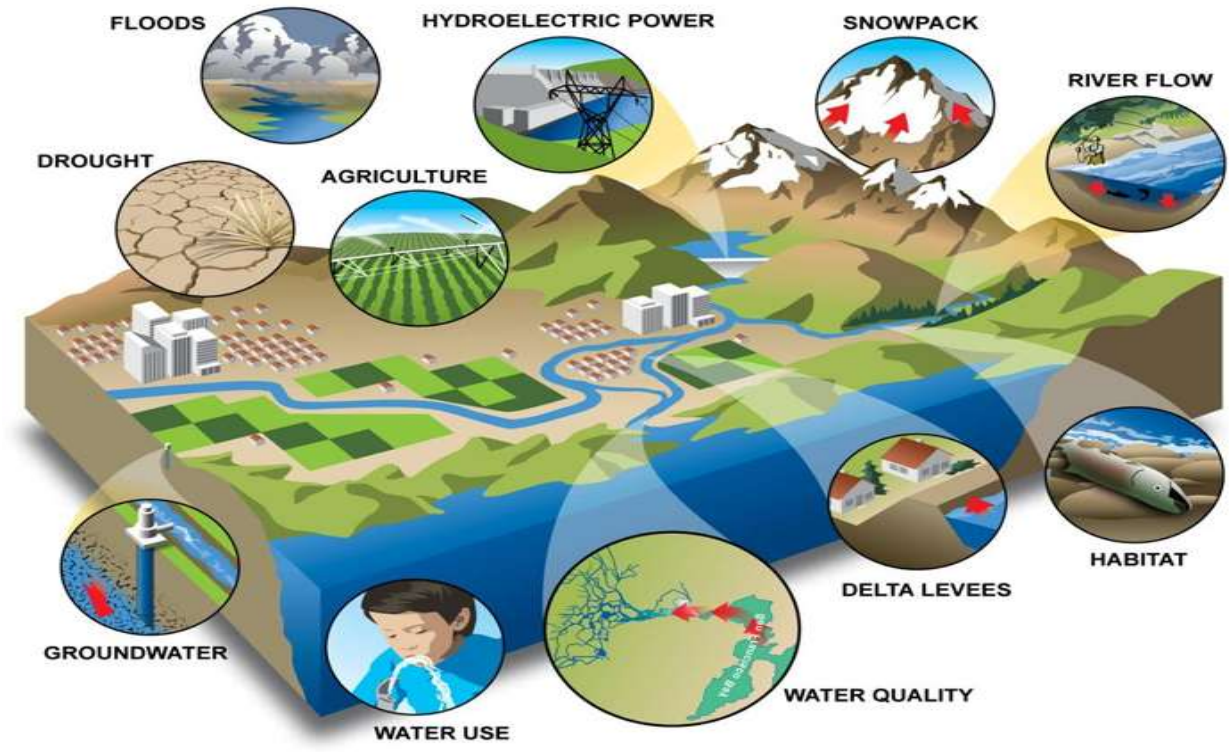


Figure 2

Chapter 2

2. The effect of climate change on water resources systems:

Several hydrological variables and characteristics of the water resources systems may be affected by global climate change.

A brief reference to these variables and characteristics is made below:

a) Temperature: Impacts of global climate change on temperature are perhaps the most obvious ones and are particularly important because temperature is a driver of many other hydrological variables.

b) Precipitation: Together with temperature, precipitation is the second hydrological variable considered in the global climate models to express the impact of global climate changes.

c) Evapotranspiration: An increase of temperature normally leads to an increase of potential evapotranspiration, although actual evapotranspiration is conditioned by the amount of water available in the soil and plants. Transpiration of water by plants is affected by a number of variables, including stomatal behavior and concentration of CO2 in the atmosphere.

d) Soil Moisture: Temperature, precipitation and evapotranspiration directly affect soil moisture. But the strongest influence is normally due to precipitation. Soil moisture changes influence strongly crop growth and water needs for irrigation.

e) Runoff: Runoff is clearly affected by the above-mentioned hydrological variables and, in particular, by precipitation. However future runoff is also conditioned by several other climatic factors and human influences, such as streamflow diversions and regulation or interaction between surface and groundwater, which makes difficult to predict future runoff.

f) Groundwater: Changes in the magnitude and seasonal distribution of precipitation will cause changes in the patterns of seasonal aquifer recharge with consequences for the groundwater stocks and flows and for the quality-

of groundwater. The interaction between surface water and groundwater is also expected to be modified.

g) Floods and Droughts: In parallel with the impact of climate change on the average values of hydrological variables, the impact on extreme phenomena, such as floods and droughts, is also relevant. Several studies indicate a tendency for an intensification of climate variability in situations of climate change and offer, for some regions, apparently paradoxical scenarios of increase in both floods and droughts.

h) Aquatic Ecosystems: Climate change may affect aquatic ecosystems in many different ways as the health of ecosystems depends of many climate-sensitive factors, including temperature, water quantity and quality, and timing of water availability. These impacts may be particularly serious in lakes and reservoirs, where important changes in the dynamics of these water bodies may lead to alterations of nutrient exchanges or to invasions of exotic species.

i) Water Quality: Climate change may affect the quality of water bodies as a consequence of changes in runoff, changes in the pattern of transport of agricultural, industrial or domestic pollutants or modification of the assimilation capacity of pollution by the water bodies related to changes in water temperature.

j) Water Demand: The changes in temperature associated to global climate change will not only have an impact on water availability but, also, on water demand. This impact will tend to be particularly relevant in the case of water use for agriculture, as a result from changes of evapotranspiration and soil moisture, but may also be significant in the cases of industrial and domestic uses.

k) Sea Level Rise: The temperature increase associated to global climate change will cause a rise of the sea level as a consequence of thermal expansion of the ocean waters and melting of glaciers and polar ice. This will have negative impacts on water resources, causing saline intrusion in coastal aquifers and affecting coastal and estuarine ecosystems.

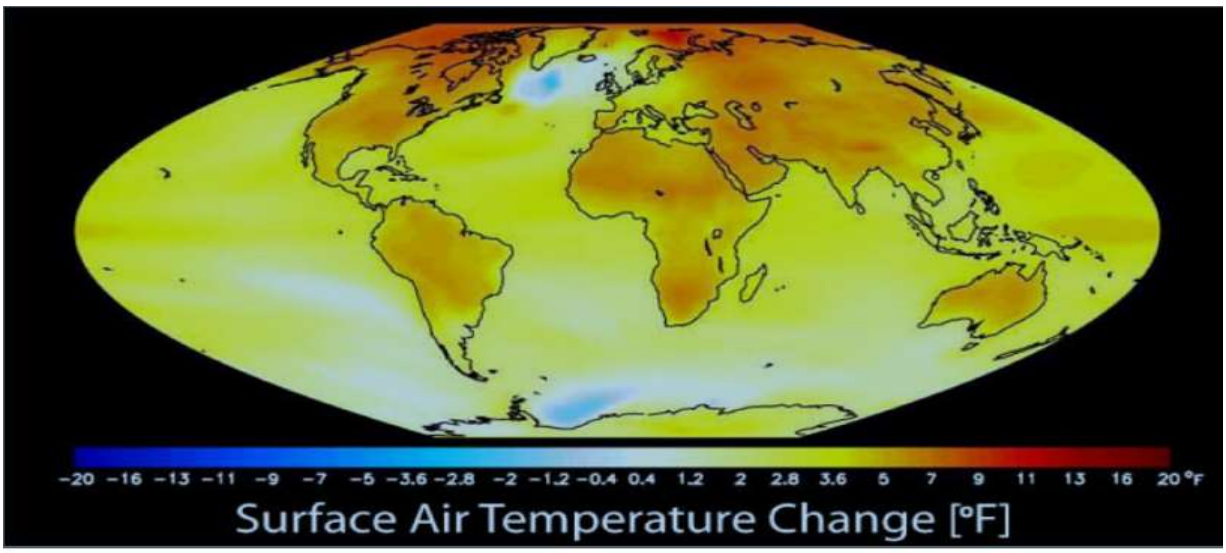
Chapter 3

The main climate change consequences related to water resources are increases in temperature, shifts in precipitation patterns and snow cover, and a likely increase in the frequency of flooding and droughts.

3. Global Temperature Changes

The Intergovernmental Panel on Climate Change (IPCC) projects that the average surface temperature of the Earth is likely to increase by 3.2 °F to 7.2 °F (1.8 °C to 4.0 °C) by the end of the 21st century, relative to 1980-1990 (IPCC, 2007c).

- As seen in Figure (3) warming is not predicted to be evenly distributed around the globe.



Projected change in annual mean surface air temperature from the late 20th century (1971-2000 average) to the middle 21st century (2051-2060 average). The change is in response to increasing greenhouse gases and aerosols based on a *middle of the road* estimate of future emissions. Warming is larger over continents than oceans, and is largest at high latitudes of the Northern Hemisphere. These results are from the GFDL CM2.1 model but are consistent with a broad consensus of modeling results.

Figure 3 surface air temperature Change

- Land areas will warm more than oceans in part because of the ocean's greater ability to store heat.
- High latitudes will warm more than low latitudes in part because of positive feedback effects from melting ice.
- Most of North America, all of Africa, Europe, northern and central Asia, and most of Central and South America are likely to warm more than the global average.
- Projections suggest that the warming will be close to the global average in south Asia, Australia and New Zealand, and southern South America.
- Warming will differ by season, with winters warming more than summers in most areas.

3.1. Effect of Temperature changes on Water Resources

An increase in the air temperature will cause water temperatures to increase as well as water temperatures increase, water pollution problems will increase, and many aquatic habitats will be negatively affected as shown in (Figure 4)

Figure 4

For example, increases in water temperatures are expected to result in the following:

- Lower levels of dissolved oxygen due to the inverse relationship that exists between dissolved oxygen and temperature as shown in (Figure 5). As the temperature of the water increases, dissolved oxygen levels decrease.

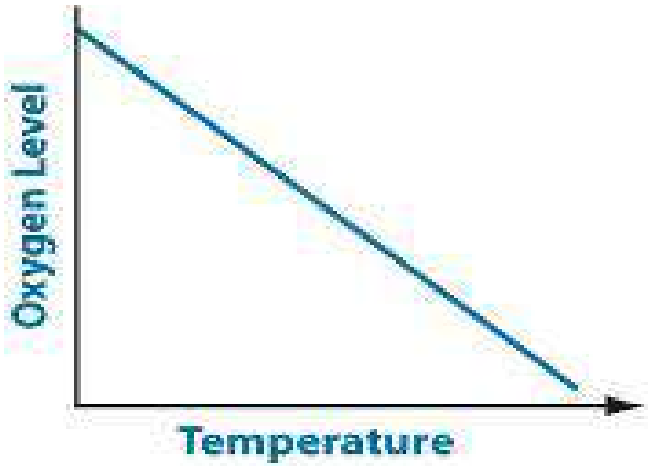


Figure 5

- Increases in pathogens, nutrients and invasive species.
- Increases in concentrations of some pollutants such as ammonia and pentachlorophenol due to their chemical response to warmer temperatures.
- Increase in algal blooms as shown in (Figure 6).

Figure 6 Increase in algal blooms

- Loss of aquatic species whose survival and breeding are temperature dependent.
- Change in the abundance and spatial distribution of coastal and marine species and decline in populations of some species.
- Increased rates of evapotranspiration from waterbodies, resulting in shrinking of some waterbodies such as the Great Lakes.
  As shown in figure (7)

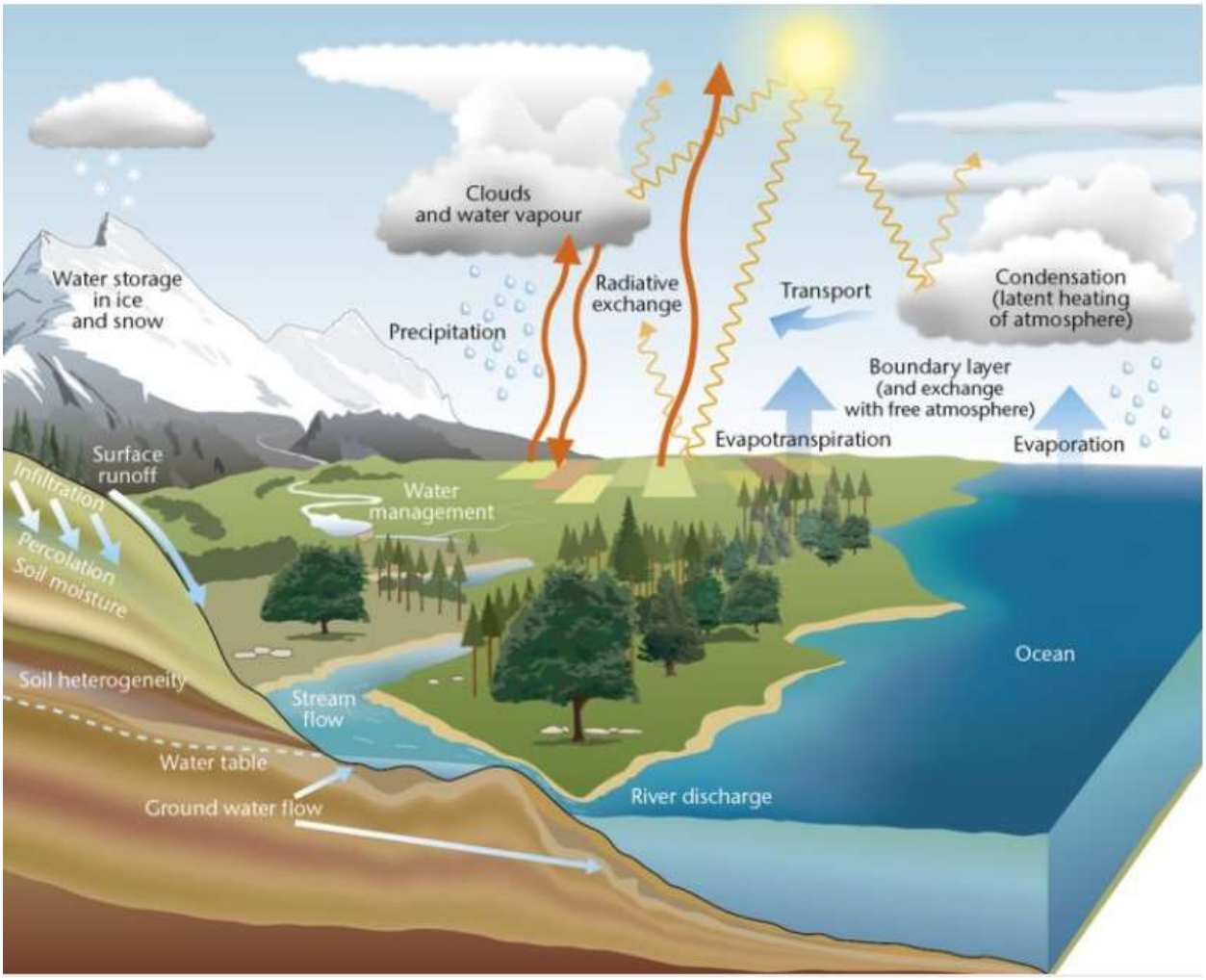


Figure 7

Chapter 4

4. Precipitation changes

As the air temperature warms, the rate at which water evaporates from soils and waterbodies increases, and that increases the amount of water being held in the atmosphere. Because there is more atmospheric moisture, there are heavier downpours when it rains. While moderate increases in annual average precipitation are expected, there is likely to be a wider variation in the pattern of rainfall, specifically, drier dry periods punctuated by more intense rainfall, as shown in Figure (8).

Figure 8 dry periods

4.1. Effect of Precipitation changes on Water Resources

Changes in the location and amount of precipitation will affect water availability and water quality (Figure 9).

- **Water availability:**
  The net impact on water availability will depend on changes in precipitation (including changes in the total amount, form and seasonal timing of precipitation). In areas where precipitation increases sufficiently, net water supplies might not be affected or they might even increase. If the precipitation remains the same or decreases though, net water supplies would decrease. This is in part due to the predicted temperature rise in most areas, which will cause evaporation rates to increase. Where water supplies decrease, there is also likely to be an increase in demand as a result of higher temperatures, which could be particularly significant for agriculture and energy production (the largest consumers of water) and also for municipal, industrial and other uses.

- **Water quality:**
  Changes in the timing, intensity and duration of precipitation can negatively affect water quality. Flooding, a result of increased precipitation and intense rain storms, transports large volumes of water and contaminants into waterbodies. Flooding also can overload storm, combined sewer and wastewater systems, resulting in untreated pollutants directly entering waterways. In regions with increased rainfall frequency and intensity, more pollution and sedimentation might be produced because of runoff. Reduced rainfall can also result in more frequent wildfires, and land areas where wildfires have occurred are more vulnerable to soil erosion.

Water availability

- Reduced ground water and surface water supply in some areas
- Increased water demand due to higher temperatures

Water quality

- Increased runoff resulting in erosion and sedimentation
- Overwhelmed water infrastructure due to flooding

Figure 9

Chapter 5

5. Conclusions

Water resources problems under conditions of global warming were the main focus of our report. The accurate forecasting of effects on water resources in the future depends on good meteorological and climatic forecasting but foremost on determining social scenarios. Changes in population and land use dynamically affect hydrologic cycles and water use directly, and substance cycles and human activities indirectly. Policies also influence human activities and water resources, but models have not been established for those influences yet. With regard to future water, more uncertainty exists in social forecasting than in hydrological and climatic models. It is clear that accurate predictions of social actions in the future are most important to predicting future water resources

Many researchers are doing their best right now to get an understanding of future water problems and adaptations to global warming.

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