Anthropogenic Influences and Their Impact on Global Climate

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Abstract

Scientist has raised some concerns with the current rise of temperature throughout the world. Researchers illustrate the correlation of environmental issues to global warming due to anthropogenic impacts. Environmental issues such as population growth, degradation of land and air pollution has influence the biogeochemical and biogeophysical process of the climate system. This review focuses on five different researches on land use, land cover, physiological response of species to climate change, tropical cyclones and, groundwater. Analyzing these reports will help understand the effects of climate change and their association with one another.

Introduction

Anthropogenic activities are one of the primary causes of global warming. Various types of ongoing research are being done to understand the relationship of human activities and their impact on global climate. Studies have shown that climate temperature has been rising and it's causing for polar ice caps to melt at a quicker rate, intense weather phenomena, and rising sea level. With the growing population, it is necessary for researchers to assess the effects of land changes that are being made by humans. In addition, natural process such as biogeochemical and biogeophysical process can influence global climate. Combining these factors can assist scientist in understanding how the elements impact the ecological and biological aspect.

The increase in global temperature also impacts the sea surface temperature as well as water availabilities. Weather intensity has been rising in the recent years and researchers have put forth in understanding these weather trends. These type of phenomena much be carefully

researched and analyze to understand what types of factors that are creating these trends. Understanding the causality of global warming can help determine a sustainable plan.

Land Use

Amanda Barr conducted a research on the interconnectivity between land use and global warming. She illustrates the influence of environmental issues through land degradation and its effects on the atmospheric and ocean temperature and its composition. As a result these environmental issues, Intergovernmental Panel on Climate Change (IPCC) reported that the earth's temperature will continue to rise over the course of 100 years due to the imbalance of incoming solar radiation and outgoing thermal radiation. (Barr, 2006)

Her report illustrates that ongoing deforestation is one of the leading causes of the increase of carbon dioxide in the atmosphere. Deforestation has had a significant negative impact since a huge amount of vegetation and soil that stores carbon are being sequestered. Clearing of the forest due to agriculture and ranch use, urbanization, logging, and the failure to preserve are the major influence of the imbalance of the carbon cycle. Carbon dioxide has had a 31% increase since the Industrial Revolution and as of 2002 there has been a 45% increase due to loss of forest cover. (Barr, 2006) To minimize the greenhouse gas in the atmosphere, she states that proper land management should be implemented.

Another factor to the increase of carbon dioxide in the air, are desert ecosystems. Her research states that it is possible for soils and vegetations in deserts to provide carbon sinks. Due to climate change, precipitation and distribution of temperature can change in the desert areas.

She finds that with 37% of the global land are desert and semi-desserts which "studies predict that with a 50% increase in carbon dioxide, plant production could be enhanced as much as 70% in desert systems." (Barr, 2006) While global warming may have a positive effect in the desert regions, a drier negative outcome will be experience in parts of the world.

The last influence in the increase of global temperature is urbanization. With the growing population, it is necessary for political parties to issue a proper future development plan. Barr states that ignoring the issues of urbanization can have a global negative impact such as increase in sea level, drought, urban heat island, depletion of groundwater, enhanced or decrease in precipitation, rising temperature and greater catastrophic hurricanes. The Environmental Protection Agency (EPA) suggests that cities around the world should implement a plan in order to reduce global warming and alleviate the negative impact that global warming might cause.

Land Cover

A different approach in understanding how climate change is being influenced is Ann Thijs's research on land cover. Along with Barr, Thijs states that with the growing population around the world, humans have altered approximately 33-50% of land surface. Thijs takes a closer look in tropical, boreal deforestation, desertification and urban heat island to understand their influence in climate change. She explains that land cover and climate are a biogeochemical and a bigeophysical process. Altering land cover will affect the biogeochemical process of atmosphere composition while "biophysical affects the energy balance of the Earth's surface,

through changes in albedo, surface hydrology, vegetation transpiration and vegetation structure." (Thijs, 2005)

Thijs used the Amazonia case study to analyze the results of altered land cover. She learned through atmospheric general circulation models (AGCM's) simulations that significant increase and significant decrease in evapotranspiration over Amazonia is due to deforestation. Decline of evapotranspiration will result into an overall surface temperature increase, dryer planetary boundary layer and atmosphere and decrease in precipitation due to the reduced water cycle. Her further investigation led her to Snyder et al (2004) vegetation and land cover removal simulation of different biomes. She discovered that the result of the simulation showed a significant impact on regional climate change. Although the data she has observed states a strong case, she expresses that the impact depends upon the tropical region.

Boreal forest was the second region that factors into climate change. She researched another Snyder et al (2004) study of biome removal in which boreal forest had the largest signal of global temperature. (Thijs, 2005) Studies illustrated that the change of land cover affects the climate systems through water balance while the vegetation alter the surface radiation balance. Thijs also examined a different simulation by Thomas, Rowntree, and Bonan et al (1992) that illustrated the climate effect of a changing albedo due to change in land cover. Data shows that by removing vegetation to reveal snow cover resulted in an increase of albedo as well as a strong reduction in net radiation, surface temperature, and precipitation. (Thijs, 2005) In addition, the effects of land cover change are driven by seasonality in the boreal forest.

The third case study that Thijs examined was the desertification in Sahel. "Desertification has been defined to be land degradation in arid, semi-arid and dry subhumid areas resulting from various factors, including climatic variation as well as human activities." (Thijs 200_) Although it has been known that the cause of desertification is due to human degradation such as overgrazing, and overcultiviation, Thijs illustrated that climatic variation is the other factor that heightens desertification. It is Sahel's regional characteristics such as sandy and non vegetated soil that maintains thermal equilibrium in which explains the extensive drought that it experiences.

Studying the Sahel desert, Thijs learned that the sea surface temperature (SST) played another role to its desertification. An extensive research by Charney showed that SST anomalies and the contrasting patterns of wet and dry periods of Sahel added to its rainfall reduction. Although SST may have been an influence, statistic shows that it was a small association and for it to have a big impact, all the other factors such as vegetation cover and soil moisture must be included.

Last land cover change Thijs touched upon was urban heat island (UHI). Due to the growing population around the world, urbanization is considered to be the most pervasive of land cover change. Regional areas a being replaced by concrete and buildings in which creates an urban heat island due to heating-ventilation-air conditioning systems, energy emissions from industrial process, and motorized vehicles. (Thijs, 2005) These anthropogenic influences have

had an effect to local temperature by creating a heat island as well as a correlation to long-term high temperature records due to air pollution, heating and cooling cost.

Physiological Responses of Species to Climate

While Barr and Thijs focuses on land use and cover, Betsy Reardon's research directs her attention on how species respond to climate change. She states that species are more susceptible to global warming due to the range of their geographical niche. Her research analyzes species migration, sex ration, reproduction, and phenology. Reardon creates an understanding on how climate change significantly influences species way of life.

Reardon states that species have a distinct geographic range in the world in which it inhibits. Although many species are limited to a restrictive range, some have a large geographical range. "Factors controlling range size may include climatic tolerances, resource availability, mate availability, or environmental needs." (Reardon, 2007) Species limit and expand their range through resource needs, fluctuating environment, climate, and human development.

Examining the North Atlantic Oscillation (NAO) model, Reardon finds that there is some correlation with the global climatic phenomena and species migration in the southeastern North Sea region. Data shows that the trend of 24 bird species was influenced by the increase of temperature in the spring. Although there was an increase in migration, it is stated that there are other environmental factors that have affected the birds such as warmer spring with higher precipitation are more likely to have higher insect population.

Another component that influences species migration is the El Nino Southern Oscillation (ENSO). ENSO significantly influences specie population in different areas due to the large scale precipitation that it brings. For instance, Reardon states that the result of ENSO in Jamaica is a dryer winter season in which decreases available foods for certain bird species. The impact of NAO and ENSO does not limit to bird species, it also affects butterflies and moth species. It is clear that climate change and resource factor is influenced by NAO and ENSO which significantly determines the migration pattern of various species.

Reardon continues her research with the climate change and its correlation to species sex determination. Although sex determination with humans are determined through sex chromosomes, various species mainly reptiles based their sex through the environments temperature. "Typically above one temperature, the individual will develop the hormones that lead to female development." (Reardon, 2007) It was stated that a case study by Janzen through the studies of turtles, a 2ºC increase in temperature drastically skews sex determination to females. While sex determination mostly affects reptiles, other animals such as bats have had skewed sex ratio. It is necessary to be aware on how species are influence by increase in temperature because if male animals are incapable of adapting, then it is very likely for species to become extinct.

Coupled with migration is reproduction. It was studied that "migratory species relocate periodically to exist in optimal environment conditions as well as the end of its migration creating a force of breeding season." (Reardon, 2007) Within the migration and its peak of

breading, an abrupt temperature change can alter their behavior negatively. Reardon's research shows that a case study was done in West Africa analyzing the flycatcher's breeding environment. It presents that a 10 day shift to earlier laying date has occurred due to the rise of temperature in the past twenty years.

It is significant to evaluate phenology because timed annual events can be observed and analyze the impacts of climate change. As natural events shift, various types of complication may affect the ecological relationships of species. For instance a shift in the natural event can alter the entire species food web. Various species are not quick to adapt to the rising weather pattern and with earlier spring or an increase in precipitation, more likely it will hinder its population.

Tropical Cyclones

As discussed by Reardon, tropical cyclones affect various types of species as well as responsible for the in land damages, injuries, and loss of human life. With the recent highly active Northern Atlantic hurricane, scientist and researchers are putting more effort in analyzing the severity of the hurricane trends. Matthew Kuntz presents a study on tropical cyclones and analyzes the changes in numbers, durations, intensity, and destructiveness of this weather phenomenon.

Through Webster et al.'s studies of tropical cyclones, Kuntz discovered that over the past 35 years, the sea surface temperature (SST) has been increasing. The rise in sea surface temperature has caused the hurricane trend to increase as well as its intensity since 1995. The

research of tropical cyclones brought many arguments regarding its relationship between the increasing hurricane frequency as well as the rise in SST based on the non-relationship between saturation vapor pressure and temperature. (Kuntz, 2005) Using global modeling to simulate hurricane predictions, Webster et al. discovered that the North Atlantic Ocean has increased frequency trend and its duration by 99% level. This information concluded that global warming has a significant affect in the increase of hurricanes as well as the rise in SST. In addition, hurricane intensities of category 4 and 5 have increase in the past decade. (Kuntz, 2005)

Kuntz reviews Knutson's case study in storm intensity. He discovered that Knutson's team focused their study on the northwest tropical Pacific regions and used the Geophysical Fluid Dynamics Laboratory (GFDL) R30 along with the ocean-atmosphere climate model to observe if high-CO_2 has some type of influence with the storm pattern. The team used 51 case controlled storms to compare to the 51 case storms in a high-CO_2 climate. It was found that high-CO_2 distribution has more areas of very intense wind speeds than the 51 controlled storm cases. Although this research has concluded the response of high-CO_2, there are still uncertainties with the data. The two scientists were not able to address all the uncertainties "due to the limited data sets and lack of similar measures." (Kuntz, 2005)

It is stated that the destructiveness of cyclone is based on the total dissipation of power as well as the overall lifetime. "Although the frequency of a tropical cyclone is important, it is not by itself an optimal measure of tropical cyclone threat." (Kuntz, 2005) Through Emanuel's calculations, Kuntz illustrates the total power dissipation (PD) that Emanuel has simplified,

which is shown below. Although PD is not an accurate measurement of cyclone it is better than using the storm frequency or intensity to determine the hurricane's threat.

$$\mathrm{PDI} \equiv \int_0^\tau V_{\max}^3 \mathrm{d}t$$

Groundwater Modeling

Due to the worldwide dependency of groundwater and the depletion of above groundwater, Leslie Llado found it significant to understand how climate change impacts groundwater. Her research analyzes the elements that influence groundwater as well as the three different types of model that quantifies the correlation between groundwater and climate. The continuous studies of the global warming trend are due to the rise in temperature and its influence in the environment, severe weather phenomena as well as availability of water. Since water is a limited and primary resource in sustaining life, it is significant "to understand the pathways through which water recharges due to location or conditions as well as its response to human activity and climatic stresses." (Llado, 2006)

She states that quantifying groundwater system is a complex process due to various factors that may influence the system. Analyzing the elements that affect groundwater are "natural" and "urban" groundwater recharge system components. (Llado, 2006) Llado states that groundwater is the third largest source of water in the world in which it is greatly influenced by the

hydrological cycle. Found in Sharp's research, the natural hydrological cycle, which is (Figure 1), includes precipitation, evaporation, transpiration, sublimation, runoff, infiltration, recharge, and baseflow. Other components that are included with the natural system model are the geological structures, vegetation, and weather conditions. It is stated that modeling the natural system is very difficult due to the limited time period as well as the accessibility of information within a region.

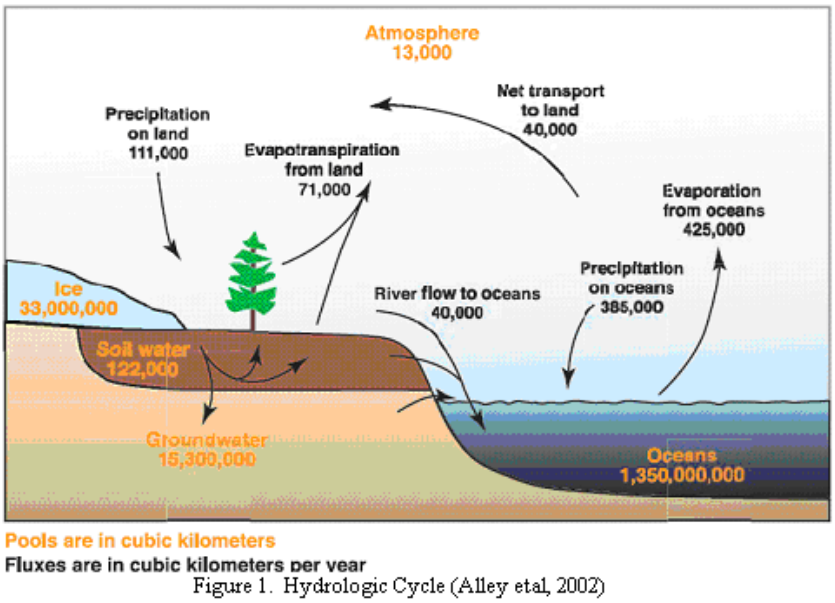

Figure 1. Hydrologic Cycle (Alley etal, 2002)

Several factors that influence a groundwater system are seasonal variations, groundwater depth, soil properties, vegetation, as well as climate. In addition, "the effect of climate on a groundwater system depends on the natural and urban groundwater components." (LLado, 2006) Depending on weather phenomena such as drought or increase in precipitation varies groundwater storage and discharge. Llado further states that regional hydrologic systems are influenced by climate change and its impacts can modify runoff, streamflow, aquifer and lake levels, soil moisture storage, and water quality.

Llado explains, based on climate models, researchers hypothesize future conditions for natural and urban groundwater components. Groundwater models are created to solve various current problems as well as predict the future outcome of the system to different types of stresses. She states that in several instances, climate change is not included in analyzing groundwater systems due to minimal past climate data information. Although general circulation models (GCMs) and land surface models (LSMs) can simulate changes in climate and produce accurate simulations, these models are not able to determine the correlation between changing soil, vegetation, and topography.

Her research looks into three different types of model that quantifies the impact of groundwater on climate systems. The three models are coupled land-atmosphere simulations (CLASP II), three-layer variable infiltration capacity model (VIC-3L), and soil hydrological model. CLASP II analyzes the decadal timescale influence of global climate on groundwater and acts like a single global climate model gridbox in which it utilizes the basic equations of conservation of momentum, thermodynamic energy, and water vapor. (Llado, 2006) Other models that are used along with CLASP II are vegetation-overland flow-soil model, MODFLOW which represent soil vegetation zones, and ATMOS which represent the atmosphere. The CLASP II along with the other models is shown below (Figure 4).

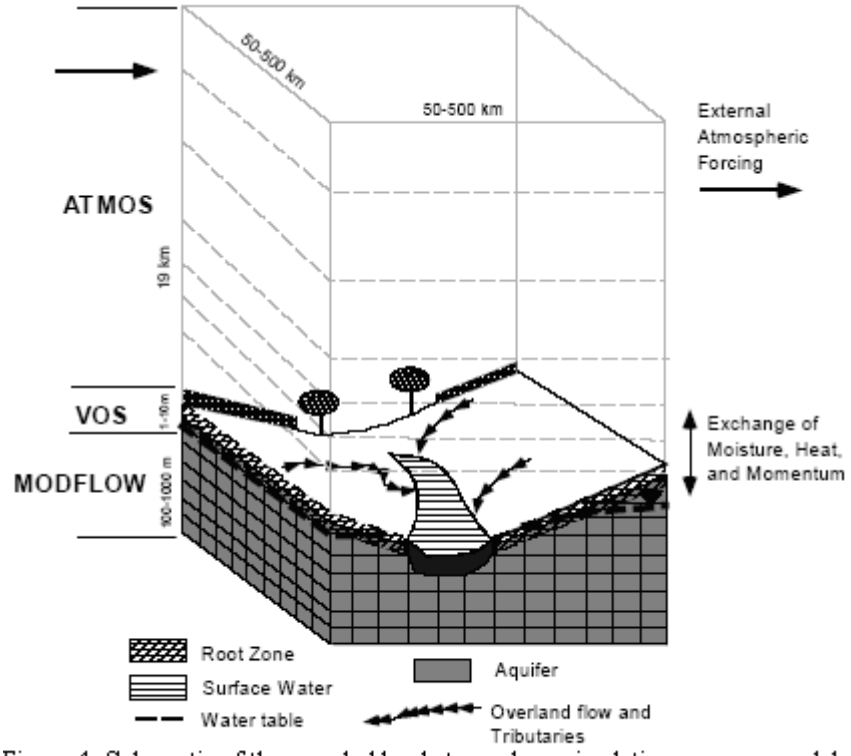

Figure 4. Schematic of the coupled land atmosphere simulation program model (York etal, 2002)

Next model she touches upon is the three-layer variable infiltration capacity model (VIC-3L). This model was improved upon by Liang and Xie in which the model successfully simulates the effect of different types of vegetation on water and energy budget. (Llado, 2006) In addition, the improved model consists of excess infiltration runoff, surface-groundwater interactions, and the effects on moisture, recharge rate, and evapotranspiration. Shown below is an example of the an experiment performed by Liang and Xie, using the VIC model, called Philip (VIC-Philip1) and Horton (Horton) and VIC (VIC-Old1) to test VIC-3L's sensitivity and correctly simulate total runoff and groundwater table position. (Llado, 2006)

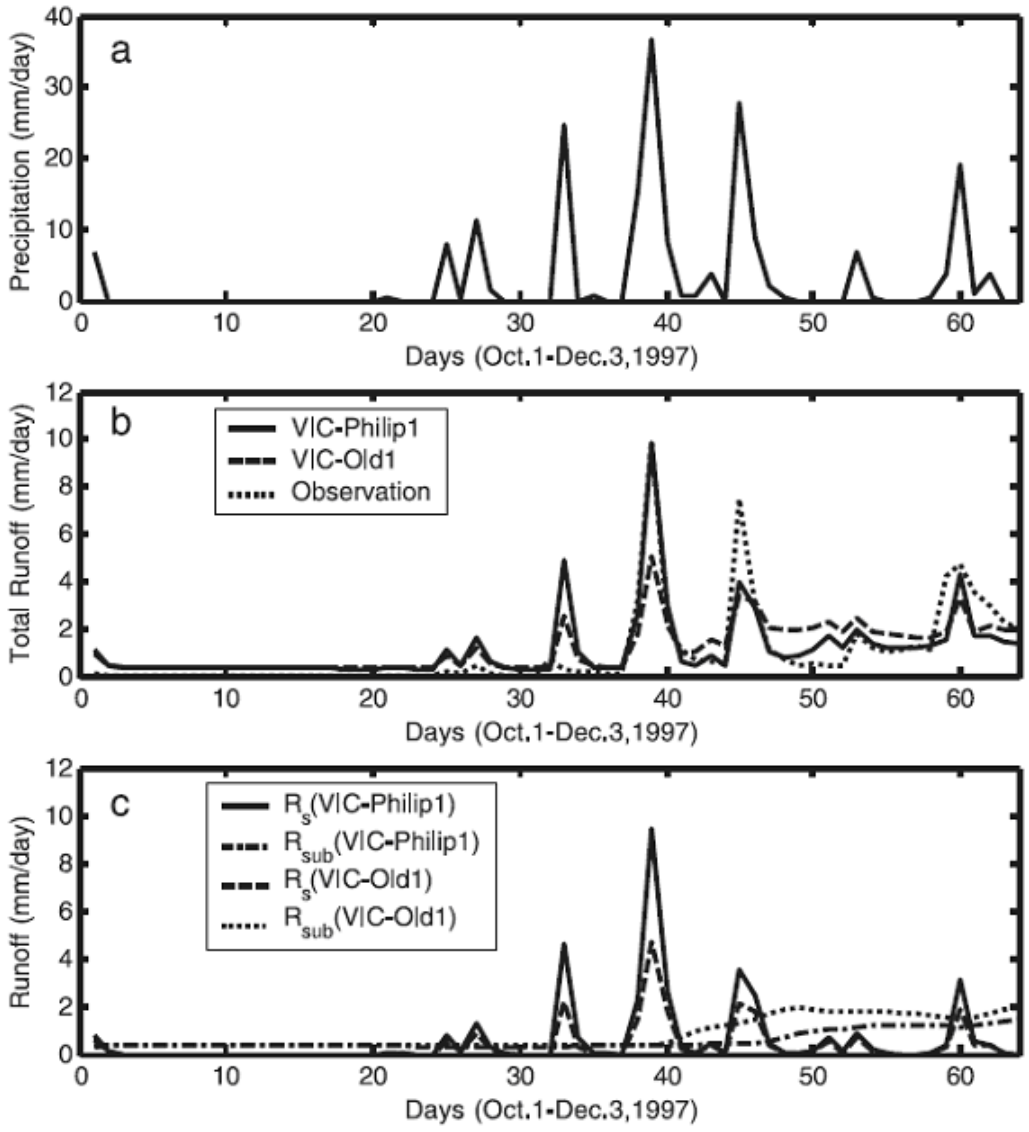

Figure 5. Comparison of model simulation at the watershed of Little Pine Creek in Pennsylvania for the period of October 1 to December 3, 1997. (Liang and Xie, 2003)

Last model that Llado illustrates is the soil hydrological model. This model was created by Chen and Hu in which it recognizes the impact of groundwater as a soil water source as well as the water exchange between the unsaturated zone and groundwater. Due to the various vertical distribution of saturated hydraulic conductivity, Richard's equation is included to calculate the soil moisture and consider the four soil layers. It is substantial to understand these

models to analyze short time periods of the impact of climate change on groundwater. Shown below is the soil hydrological model (Figure 6) and below is Richard's equation.

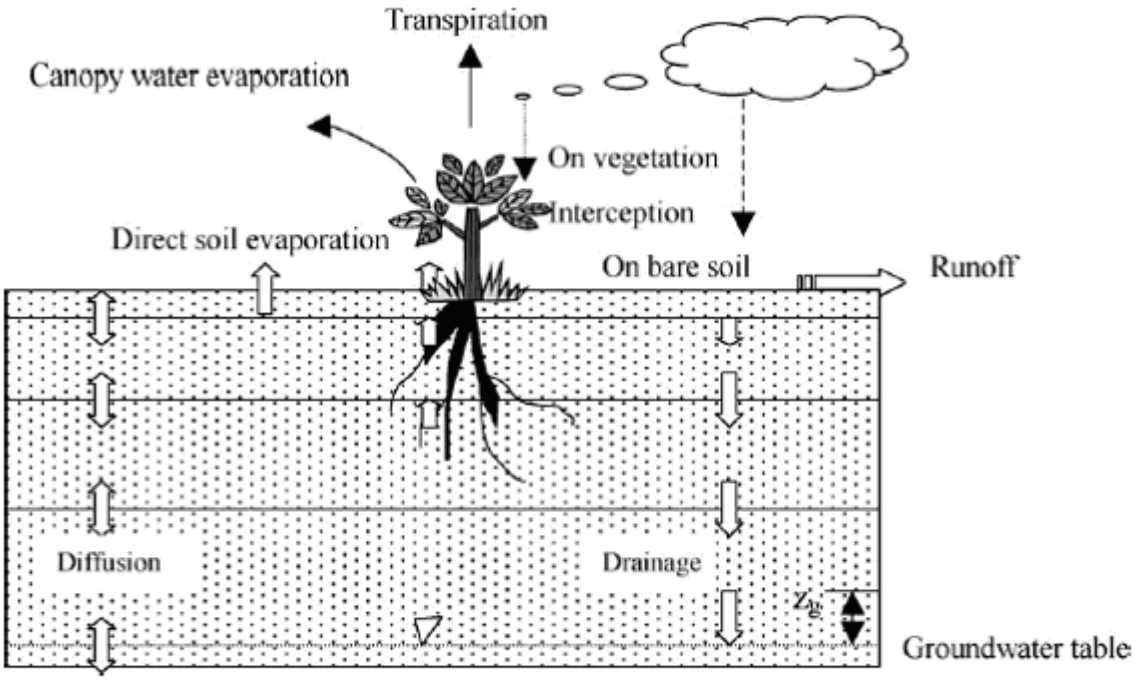

Figure 6. A Schematic of the multiplayer soil hydrological model.
(Chen and Hu, 2004)

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial z}\left(D\frac{\partial \theta}{\partial z}\right) + \frac{\partial K}{\partial z} + F(t, \theta),$$

Equation 1. Richard's Equation.
(Chen and Hu, 2004)

Conclusion

Analyzing the factors that influence global warming is quite complex. There are various elements that affect the physical, biological, and ecological aspect of an area such as land use and land cover. Climate is a significant process that greatly affects species and the biogeochemical and biogeophysical process. Creating and using climate models and groundwater models can help researchers understand the scientific process of global warming. In addition, researchers can compare and improve models to help determine a more accurate data. These ongoing simulations are beneficial to the world because scientists are able to create hypothesis, which in turn help educate the world and motivate people to live a more sustainable lifestyle.

References

Barr, Amanda. *Change in Land Use: Impacts for Global Warming.* November 2006, Accessed Online, http://www.geo.utexas.edu/courses/387h/ScheduleGPC_detail.htm, 10 November 2008.

Kuntz, Matthew B. *The Effects of a Warming Climate on Tropical Cyclones.* 1December 2005, Accessed Online, http://www.geo.utexas.edu/courses/387h/ScheduleGPC_detail.htm, 13 November 2008.

Llado, Leslie. *A Discussion of Groundwater Modeling and Climate Change.* 30 November 2006. Accessed Online, http://www.geo.utexas.edu/courses/387h/ScheduleGPC_detail.htm, 7 November 2008.

Reardon, Betsy. *Beyond Habitat Selection: Physiological Responses of Species to Climate.* 20 November 2007, Accessed Online, http://www.geo.utexas.edu/courses/387h/ScheduleGPC_detail.htm, 13 November 2008.

Thijs, Ann. *Changes in Climate due to Land Cover Change.* December 2005, Accessed Online, http://www.geo.utexas.edu/courses/387h/ScheduleGPC_detail.htm, 10 November 2008.