Chapter 22
Projections of Future Climates

Abstract Climate projections are not the same as climate predictions. Climate change scientists can't predict the future but with knowledge of past climates and detected climate trends, it is feasible to project climate change into the future using various scenarios. The IPCC did several projections in their AR4 2007 report and these are discussed in this chapter. What will happen in a hotter, flatter, and more crowded world is something inhabitants of this planet should be concerned about. There are conditions that we can be fairly confident about as we gaze into a virtual future. The political climate is separate from the temperature but has a great deal to do with the future of Earth and its inhabitants. Some politicians are famous or notorious for their stance on climate change and their contribution to environmental issues (both positive and negative) and some are discussed in this and the following chapters. Mitigation of climate change is to slow things down and thereby improve the global temperature rise or to stop it entirely. Is it already too late to stop the globe from further warming and, if it is not, what should or can we do?

Keywords Internet • World-Wide • Web • Computers • Laptops • Hotter • Flatter • Crowded • Digital • Billion • Projections • EPRI • IPCC • IPods • Royal • Nixon • Obama • Reagan • Inhofe • EPA • Mitigation • Carbon sequestration

G.T. Farmer and J. Cook, *Climate Change Science: A Modern Synthesis: Volume 1 - The Physical Climate*, DOI 10.1007/978-94-007-5757-8_22,

Things to Know

The following is a list of things to know from this chapter. It is intended, as it is in each chapter, to serve as a guide to points of emphasis for the student to keep in mind while reading the chapter. Before finishing with this and every chapter, the "Things to Know" should be understood and can be used for review purposes. The list may not include all of the terms and concepts required by the instructor for this topic.

Things to Know	
Hotter	GHGs
Flatter	Niger
14.5°C	EPRI
More crowded	Internet
IPods	11.5°F
EPA	Digital age
$GtCO_{2\text{-eq}}$	0.2°C
Mitigation	350 ppm
IPCC 2007 projections	Royal society
200 billion	14.5°F
Future climate scenarios	Population projections for mid-twenty-first century

22.1 Introduction

Projections of current climatic conditions into the future are not the same as predicting the future. The future is impossible to predict but projecting into the future climate conditions that exist today and have been trending a certain way can be a very useful exercise.

Civilization has only recently completed the first decade of the twenty-first century. The world is a much different place than it was at the beginning of the last century. And there are already projections for the next century. Those projections do not inspire optimism as some things need to be accomplished soon or it will be too late for the planet's inhabitants, or at least too expensive to contemplate at this time.

Earth is becoming hotter, flatter, and more crowded. It is becoming hotter due to global warming caused appreciably by greenhouse gas increases which are due mainly to the burning of fossil fuels. It is becoming flatter because of the internet, the world-wide web and the use of personal computers, cell phones, tablets, and other means of world-wide communication. It is becoming more crowded because the population of human beings is growing out of control. There are ways that human beings can choose to change or mitigate the worst-case scenarios that we can see playing out in the near future of planet Earth or we can do nothing and gamble on the future of the species and other life on Earth.

22.2 Hotter – Global Warming

Since the beginning of the Industrial Revolution in the mid-1700s, the Earth's temperature has been raised approximately 0.8°C (1.4°F) and it continues to climb. About 66% (0.53°C) of the temperature increase has been since 1980. Estimates of a temperature rise up to a 10°C increase by the end of this century have been projected into the future if certain conditions are not met, one of which is to significantly reduce the emissions of greenhouse gases.

The Intergovernmental Panel on Climate Change (IPCC) in their 2007 report state that during the twenty-first century the global surface temperature is likely to rise an additional 1.1–2.9°C (2–5.2°F) for their lowest emissions scenario and 2.4–6.4°C (4.3–11.5°F) for their highest. It is likely to rise higher and unlikely to be lower by the end of this century (the twenty-first century).

The global average temperature in 2011 was 14.52°C (58.14°F). According to NASA scientists, 2011 was the ninth warmest year in 132 years of recordkeeping since 1879, despite the cooling influence of the La Niña atmospheric and oceanic circulation pattern and relatively low solar irradiance. Since the 1970s, each subsequent decade has gotten hotter, and 9 of the 10 hottest years on record have occurred in the twenty-first century. There is no doubt, despite what the deniers are saying, the thermometers, Agro floats, climate models, and satellites worldwide are not lying; the Earth is warming and global warming is real.

22.3 Flatter – The Digital Age

The internet and the world-wide web (www) have made almost instantaneous global communication available to nearly everyone on the planet; and this, combined with web browsers and smart phones, has made the world flatter. Within the last decade of the twentieth century and the first in the twenty-first, technological innovation in the form of communication and economy has caused a globalization and a fundamental change in the way that humans communicate that has been a revolution. No longer does humanity depend on airmail, snail mail, pony express, long-distance land-line telephones or other means of slow communication when we can receive stock market reports, environmental study reports, email, instant messages; spy satellite downloads all in a matter of seconds. The world is flatter.

By stating that the Earth is getting flatter, it is obviously not intended to convey that the planet is physically getting flatter. Earth remains a globe, an oblate spheroid that circles the Sun in 1 year and rotates on its axis in 1 day. But the global economy is allowing more and more people to join the middle class, to join in the advances that are impacting the middle class, such as being able to purchase personal computers, laptops, cell phones, a family residence, and other personal items that were out of their reach before the twenty-first century. Global communications and a global economy are making the world flatter.

The personal computer has been a symbol of the new middle class. For the first time in the history of the world, it has allowed individuals to partake in the world economy and to join a world community. It has allowed individuals to obtain information that previous generations could not even dream of obtaining. And this has come about only in the last couple of decades, with the advent of the Internet, the World-Wide Web, the web browser, and the digital age in general. Humans now live in a world of 1 and 0s, a digital world and a flatter world.

Along with the personal computer, the Internet and the World-Wide Web, was a revolution in the use of software transmission protocols that improved workflow. People could work on the same projects in different parts of the world; for example an industrial engineer in California could work with a scientist in Japan and a software engineer in New York to devise a new program to assist a manufacturing project in Montreal. Report writers in Moscow and Philadelphia could work with writers in Harrisonburg, Virginia to complete a report for the soccer team in Manchester, England. Computer programmers could share code (open source) throughout the world and thousands of people could make suggestions and improve the software. The world was becoming even flatter.

22.4 More Crowded – Population Increase

The illustration below (Fig. 22.1) shows the planet's growth in population from 1800 to the present and projected growth to 2100. The rapid increase in the world's population has been supported by science and technology; Watt's coal-fired steam engine, Haber and Bosch synthesizing nitrogen fertilizer, Fleming's discovery of penicillin and these science and technology advances continue today as the world's population expands at the rate of 78 million people per year. As birth rates increase in many parts of the world, people's increasing life span, and improving health care for millions of humans, the world's population increase is a cause for concern.

Rapid and widespread changes in the world's human population, coupled with unprecedented levels of consumption present profound challenges to human health and wellbeing, and the natural environment as well as for the future of the planet.

The combination of these factors is likely to have far reaching and long-lasting consequences for our finite planet and will impact on future generations as well as the present one. These impacts raise serious concerns and challenge us to consider the relationship between people and the planet. It is not surprising then, that debates about population have tended to inspire controversy.

The Royal Society (London) in an April 28, 2012 report entitled "People and the Planet" made the following recommendations:

Key recommendations include:

- The international community must bring the 1.3 billion people living on less than $1.25 per day out of absolute poverty, and reduce the inequality that persists in the world today. This will require focused efforts in key policy areas including economic development, education, family planning and health;

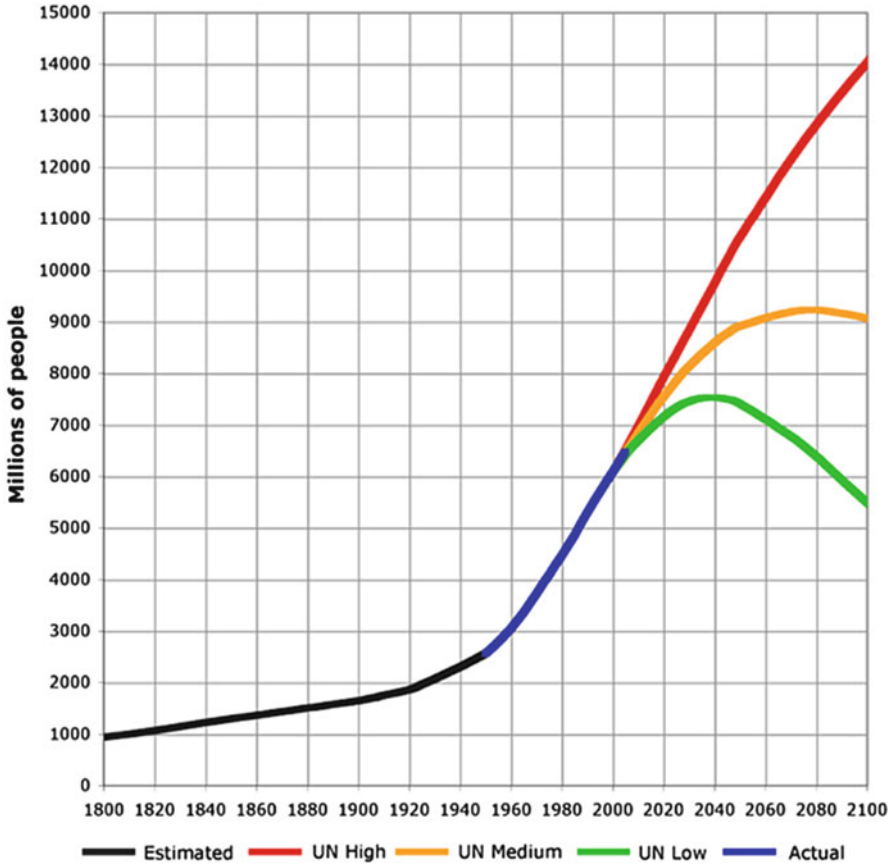

Fig. 22.1 World population from 1800 to 2100 based on United Nations 2004 projections and U.S. Census Bureau historical estimates (From Wikipedia, Loren Cobb (User: Aetheling), GNU Free Documentation License)

- The most developed and the emerging economies must stabilize and then reduce material consumption levels through dramatic improvements in resource use efficiency, including: reducing waste; investment in sustainable resources, technologies and infrastructures; and systematically decoupling economic activity from environmental impact;
- Reproductive health and voluntary family planning programs urgently require political leadership and financial commitment, both nationally and internationally. This is needed to continue the downward trajectory of fertility rates, especially in countries where the unmet need for contraception is high;
- Population and the environment should not be considered as two separate issues. Demographic changes, and the influences on them, should be factored into economic and environmental debate and planning at international meetings, such as

the Rio+20 Conference on Sustainable Development and subsequent meetings (the first of which recently completed in June 2012).

Other recommendations made in the report focus on:

- The potential for urbanization to reduce material consumption;
- Removing barriers to achieve high-quality primary and secondary education for all;
- Undertaking more research into the interactions between consumption, demographic change and environmental impact;
- Implementing comprehensive wealth measures;
- Developing new socio-economic systems.

22.4.1 Population and Demographics

The advances in technology during the last half of the twentieth century and the beginning of the twenty-first, the collapse of the Soviet Union, and the fall of the Berlin Wall freed about 200 million people from the clutches of economic and social depression and brought them into the global marketplace. These advances allowed more millions to buy and sell more goods than ever before and have contributed to the advancement of obtaining a middle class existence for themselves and their families. They wanted cell phones, iPods, laptops, cars, houses, air conditioning, televisions, and anything else that would help them attain the "American dream." Thus society became the "throw away" society, increasing the size of landfills and other deleterious impacts on human services. They also became part of the "instant gratification society" and contributed to the age of the "sound bite."

The American diet of McDonalds, Burger King, Kentucky Fried Chicken (KFC), and fast food in general expanded globally which led to obesity as a world-wide problem with its plethora of adverse health effects. Additional health effects from increased groundwater contamination, inadequate sewerage treatment, and the direct effects of global warming, such as floods and droughts and the spread of tropical diseases will cause further impacts on the well being of the human race.

The United Nations Population Division, in a report issued March 13, 2007, stated that the world population was approaching seven billion (which it attained in October 2011) and it would likely increase by 2.5 billion in the next 13 years reaching 9.5 billion by 2050. This increase is equal to the total global population in 1950. The majority of these new people will be in the less developed countries whose population is projected to rise from 5.4 billion in 2007 to 7.9 billion by 2050. The population of the more developed countries will remain largely unchanged.

Urbanization will have to accommodate the large majority of the population increase and they are not prepared for it; they do not have the resources, transportation systems, or other infrastructure necessary for the increased number of inhabitants.

In 2008 more than half of humanity lived in cities. In 1800, London was the world's largest city with one million people. On April 28, 2012 the world's population was 7,009,819,056 and over 300 cities had over a million people.

Megacities are defined as those with over ten million inhabitants. According to the United Nations, there were five megacities in 1975, 14 in 1995, and their number is expected to reach 26 by 2015. By 2030 the number of city dwellers is projected to be five billion.

Most of the population growth will take place in cities of around 500,000, according to the United Nations. These cities do not have the infrastructure to handle such rapid growth. Water, sewer, health services, food, shelter, and other services will be overwhelmed. Classical methods of urban planning will be obsolete as these smaller cities grow beyond their capacity. Modern transportation will also become obsolete as more and more people will use public transportation as the cities grow.

The most rapid population growth will occur in underdeveloped countries that can least afford it. According to the U.S. Central Intelligence Agency (CIA), poor and fragile states like Afghanistan, Niger, Liberia, the Sudan, and the Democratic Republic of the Congo will have rapidly growing populations, some estimates calling for a tripling of their populations by mid-century. The populations in countries like Ethiopia, Nigeria, and Yemen are projected to double in size. A large percentage of the increasing population will be younger people in search of food, housing, education, jobs. If the needs of these younger people are not met, there is a great chance they will resort to violence, civil unrest, and religious extremism.

Thomas L. Friedman, in his 2008 book entitled "Hot, Flat, and Crowded," quoted David Douglas, a vice president of Sun Microsystems, who commented that when the newest billion people arrived, we give each of them a 60-W incandescent light bulb, as follows:

"Each bulb doesn't weigh much – roughly 0.7 ounces with the packaging – but a billion of them together weigh around 20,000 metric tons, or about the same as 15,000 Priuses. Now let's turn them on. If they are all on at the same time it would be 60,000 MW. Luckily, they will only use their bulbs 4 h/day, so we're down to 10,000 MW at any moment. Yikes! Looks like we'll still need twenty or so new 500-MW coal-burning power plants" just so the next billion people can turn a light on.

Coal-burning power plants are among the planet's greatest sources of carbon dioxide emissions to the atmosphere. The advertisements by coal companies and the Electric Power Research Institute (EPRI) about "clean coal" are misleading. "Clean coal" is an oxymoron; it doesn't exist. Use of the term is a lie and the advertisements using the term are lies and the general public and good citizens of this planet need to know this. Coal is one of the dirtiest fuels on the planet, only exceeded by oil sands and lignite and the majority of coal throughout the world is strip-mined in the Appalachians in the eastern United States. The total cost of mining coal is astronomical when the cost of health effects, mine explosions and deaths, damage to the local ecology, and stream and groundwater contamination are factored into the process.

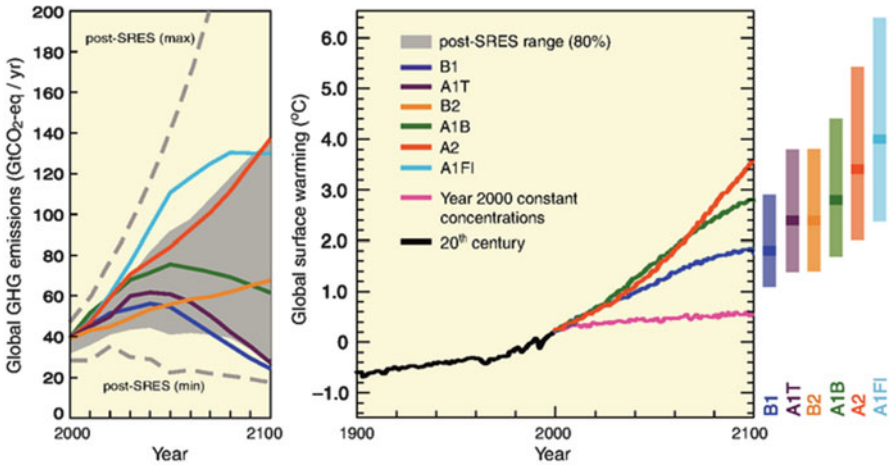

Fig. 22.2 *Left Panel*: Global GHG emissions (in $GtCO_2$-eq) in the absence of climate policies: six illustrative SRES marker scenarios (*colored lines*) and the 80th percentile range of recent scenarios published since SRES (post-SRES) (*gray shaded area*). *Dashed lines* show the full range of post-SRES scenarios. The emissions include CO_2, CH_4, N_2O and F-gases. *Right Panel*: Solid lines are multi-model global averages of surface warming for scenarios A2, A1B and B1, shown as continuations of the twentieth-century simulations. These projections also take into account emissions of short-lived GHGs and aerosols. The pink line is not a scenario, but is for Atmosphere-Ocean General Circulation Model (AOGCM) simulations where atmospheric concentrations are held constant at year 2000 values. The bars at the right of the figure indicate the best estimate (*solid line* within each bar) and the likely range assessed for the six SRES marker scenarios at 2090–2099. All temperatures are relative to the period 1980–1999 (Figures 3.1and 3.2 of the IPCC AR4, 2007 Report)

22.5 IPCC Projections of Future Climate Change

The IPCC AR4 2007 report's projections for the future are based on the four scenarios given above (Fig. 22.2). For the next two decades a warming of about 0.2°C per decade is projected for a range of scenarios in their report *Special Report on Emissions Scenarios* (*SRES*). Even if the concentrations of all GHGs and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected. Afterwards, temperature projections increasingly depend on specific emissions scenarios.

For the six SRES marker scenarios, IPCC (2007) gave a "best estimate" of global mean temperature increase (2090–2099 relative to the period 1980–1999) that ranged from 1.8 to 4.0°C. Over the same time period, the "likely" range (greater than 66% probability, based on expert judgment) for these scenarios was for a global mean temperature increase of between 1.1 and 6.4°C.

The SRES scenarios were admittedly conservative. If the Greenland and Antarctic ice sheets substantially diminish as they are now showing signs of doing, the decrease in Earth's albedo will be substantial and greater warming will take place. Land and water generally have a lower albedo than ice.

Climate change projections done by scientists other than those on the IPCC have been made using several different emission scenarios. In a scenario where global emissions start to decrease by 2010 and then decline at a sustained rate of 3% per year, the likely global average temperature increase was predicted to be 1.7°C above pre-industrial levels by 2050, rising to around 2°C by 2100. In a projection designed to simulate a future where no efforts are made to reduce global emissions, the likely rise in global average temperature was predicted to be 5.5°C by 2100; a rise as high as 7°C was thought possible but less likely (Fig. 22.3).

The IPCC AR4 2007 report also produced the table given below (Table 22.1). Scientists now are in general agreement that these temperatures and projected sea-level rise are conservative projections.

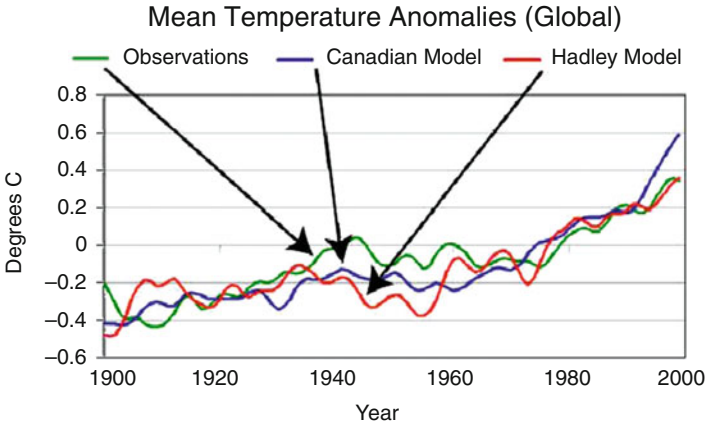

Fig. 22.3 Mean global temperatures from observations and two climate models. Trends of global temperature from observations, the United Kingdom's Hadley Centre Global Climate Model, and the Canadian Climate Center's Global Climate Model. Trends have been smoothed to remove year-to-year high frequency variations (Public Domain)

Table 22.1 Projected global average surface warming and sea level rise at the end of the twenty-first century

	Temperature change (°C at 2090–2099 relative to 1980–1999)[a,b]		Sea level rise (m at 2090–2099 relative to 1980–1999)
Case	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant year 2000 concentrations[c]	0.6	0.3–0.9	Not available
B1 scenario	1.8	1.1–2.9	0.18–0.38
A1T scenario	2.4	1.4–3.8	0.20–0.45
B2 scenario	2.4	1.4–3.8	0.20–0.43
A1B scenario	2.8	1.7–4.4	0.21–0.48

(continued)

Table 22.1 (continued)

Case	Temperature change (°C at 2090–2099 relative to 1980–1999)[a,b]		Sea level rise (m at 2090–2099 relative to 1980–1999)
	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
A2 scenario	3.4	2.0–5.4	0.23–0.51
A1FI scenario	4.0	2.4–6.4	0.26–0.59

From IPCC AR4 Report, SRES Table 3.1, 2007
Notes:
[a]Temperatures are assessed best estimates and likely uncertainty ranges from a hierarchy of models of varying complexity as well as observational constraints
[b]Temperature changes are expressed as the difference from the period 1980–1999. To express the change relative to the period 1850–1899 add 0.5°C
[c]Year 2000 constant composition is derived from Atmosphere-Ocean General Circulation Models (AOGCMs) only
[d]All scenarios above are six SRES marker scenarios. Approximate CO_2-eq concentrations corresponding to the computed radiative forcing due to anthropogenic GHGs and aerosols in 2100 (see p. 823 of the Working Group I TAR) for the SRES B1, AIT, B2, A1B, A2 and A1FI illustrative marker scenarios are about 600, 700, 800, 850, 1,250 and 1,550 ppm, respectively

22.6 Politics and Global Warming

Politicians usually go into politics because they crave power. Not all do, as witness the Kennedy family in the U.S. Some feel that they have gained so much from a political system or from a system of government that they decide that they should give back to that system. But these politicians are in a minority, in the U.S. as in many other parts of the world.

22.6.1 Politicians and Their Views

A politician's views are usually determined by their constituency, their religious convictions, or their social views. A prime example is given by the senior Senator from Oklahoma, Senator James Inhofe. Senator Inhofe has claimed to be an expert on climate change and global warming but he has proven to have little if any understanding of the subject and has had no training in any of the Earth sciences. He is the perfect example of someone with no expertise in a subject claiming to be an expert. Senator Inhofe has as his terminal degree a bachelor's degree in economics from the University of Tulsa, hardly qualifying him as an expert in climate science.

Amidst mounting worldwide concern from scientists, governments, and citizens, Inhofe glibly dismisses global warming as propaganda, as "the poster child of the Left," and, incredibly, as "the greatest hoax ever perpetrated on the American people."

22.6.2 Ronald Reagan

Ronald Reagan was the 40th president of the United States. He was previously a member of the Democratic Party, turned Republican, became governor of California, had a background as an actor, and was president of the Screen Actors Guild (SAG). He was ignorant of scientific issues and made no attempt to educate himself in any of them. He surrounded himself with scientists who supported weapons of mass destruction during the "cold war," such as S. Fred Singer (a notorious denier of global warming and an annual contributor to the discredited Heartland Institute's anti-environmental meetings in Washington, DC), and were not knowledgeable of or did not care about environmental issues. It was during the Reagan administration that the U.S. Republican Party's anti-science movement began. Reagan died of Alzheimer's disease that almost certainly had its beginnings while he was president. It was rumored that others made the decisions of the presidency in his stead while he was still occupying the Oval Office in the U.S. White House.

22.6.3 Richard Nixon

Richard Nixon was the 37th president of the United States. He established the U.S. Environmental Protection Agency in 1970. The initiatives supported by Nixon included the Clean Air Act of 1970 and Occupational Safety and Health Administration (OSHA); the National Environmental Policy Act required environmental impact statements for many Federal projects. Nixon vetoed the Clean Water Act of 1972—objecting not to the policy goals of the legislation but to the amount of money to be spent on them, which he deemed excessive. After Congress overrode his veto, Nixon impounded the funds he deemed unjustifiable.

22.6.4 Barak Obama

Barak Obama is the 44th President of the United States. During his campaign in 2008 he mentioned climate change numerous times but has accomplished little during his first term. He postponed approval of the XL pipeline, a proposed pipeline extending from Alberta, Canada to Houston, Texas to transport oil from tar sands, one of the dirtiest sources of petroleum on Earth. There is hope for more environmental accomplishments during his 2nd term, if he is re-elected in November 2012 and relatively no hope for environmental regulations mitigating global warming prior to 2016. The longer the delay, the more severe the consequences and the greater the cost.

Additional Readings

"Atmospheric Model Intercomparison Project". The program for climate model diagnosis and intercomparison, Lawrence Livermore National Laboratory, Livermore. Information about this project may be found at the following web site: http://www-pcmdi.llnl.gov/projects/amip/index.php

Friedman, T. L. (2008). *Hot, flat, and crowded: Why we need a green revolution and how it can renew America* (438 pp). New York: Farrar, Straus and Giroux.

McGuffie, K., & Henderson-Sellers, A. (2005). *A climate modelling primer* (p. 188). New York: Widely. ISBN 978-0-470-85751-9.

Meehl, G. A., et al. (2007). Climate change 2007, Chapter 10: Global climate projections, in IPCC AR4 WG1. In: S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, & H. L. Miller (Eds.), *Climate change 2007: The physical science basis*, *contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change*. Cambridge: Cambridge University Press, ISBN 978-0-521-88009-1 (pb: 978-0-521-70596-7).

Soden, B. J., & Held, I. M. (2006). An assessment of climate feedbacks in coupled ocean–atmosphere models. *Journal of Climate, 19*, 3354–3360. doi:10.1175/JCLI3799.1.

Sokolov, A. P., et al. (2009). Probabilistic forecast for 21st century climate based on uncertainties in emissions (without policy) and climate parameters. *Journal of Climate, 22*(19), 5175–5204. doi:10.1175/2009JCLI2863.1.

Wang, W. C., & Stone, P. H. (1980). Effect of ice-albedo feedback on global sensitivity in a one-dimensional radiative-convective climate model. *Journal of the Atmospheric Sciences, 37*(3), 545–552. Bibcode 1980JAtS…37..545W. doi:10.1175/1520-0469(1980)037<0545:EOIAFO>2.0.CO;2. ISSN 1520-0469.