



Governor's Action Team on Energy and Climate Change

Background Briefing: Global Climate Change

August 2007

INTRODUCTION

The issue of global climate change involves changes in the radiative balance of the Earth – the balance between energy received from the sun and emitted from Earth – that may alter weather patterns and climates at global and regional scales. The Earth's radiative balance is influenced by variations in the sun's output and concentrations of so-called "greenhouse gases" (GHG) such as carbon dioxide (CO₂), methane (CH₄), nitrous oxides (N₂O), water vapor, and other gases which trap a portion of outgoing solar energy to retain heat. Other substances, such as carbon particulates (soot) and sulfate aerosols reflect incoming solar radiation or absorb its energy to provide a counterbalance to the effects of energy retention within the atmosphere. The net effect of these opposing forces is observable in global mean temperatures over time.

The primary objective of climate change policy is to stabilize and ultimately reduce the concentrations of greenhouse gases within the Earth's atmosphere in order to avert the presumed adverse impacts of increased global mean temperatures, altered climactic and weather patterns, and the subsequent impact on humans.

The purpose of this whitepaper is to provide a synopsis of the current science of global climate change, an overview of the potential impacts of this phenomenon to the State of Florida, and a summary of policy options for consideration in framing a GHG reduction strategy for Florida.

CURRENT STATE OF CLIMATE CHANGE SCIENCE

The body of science associated with human-induced climate change is extensive. Much of the science, particularly the results of instrument-aided observation over the past 150 years, is relatively undisputed. Because climate studies by necessity address trends over centuries or even millennia, the science associated with placing these instrument-based observations within the context of past centuries and projecting observed trends forward through modeling has been more often been disputed. The following overview of climate change science is constructed from peer-reviewed studies from the most broadly accepted domestic and international science institutions.

The Global Carbon Cycle

Carbon cycles through land masses, the oceans, and the atmosphere in two primary pathways: the geological, which operates over large time scales (millions of years), and the biological/physical, which operates at shorter time scales (days to thousands of years). Of these, the biological/physical pathway is the most significant in characterizing the larger cycle. On land, the major exchange of carbon with the atmosphere results from the photosynthesis and respiration of plants and trees. During the daytime in the growing season, leaves absorb sunlight and take up CO₂ from the atmosphere. In parallel, plants,

animals and soil microbes consume the carbon in organic matter and return carbon dioxide to the atmosphere. When conditions are too cold or too dry, photosynthesis and respiration cease along with the movement of carbon between the atmosphere and the land surface. The amounts of carbon that move from the atmosphere through photosynthesis, respiration, and back to the atmosphere are large and produce oscillations in atmospheric CO₂ concentrations. Over the course of a year, these biological fluxes of carbon are over ten times greater than the amount of carbon introduced to the atmosphere by fossil fuel burning.¹

In the oceans, CO₂ exchange is largely controlled by sea surface temperatures, circulating currents, and by the biological processes of photosynthesis and respiration. Carbon dioxide dissolves easily into the ocean and the amount of CO₂ that the ocean can hold depends on ocean temperature and the amount of CO₂ already present. Cold ocean temperatures tend to uptake more CO₂ from the atmosphere while warm temperatures can cause the ocean surface to release CO₂.

In addition to the natural carbon cycle, human activities, particularly fossil fuel burning and deforestation, are also releasing CO₂ into the atmosphere. The result is that humans are adding ever-increasing amounts of extra carbon dioxide into the atmosphere. Because of this, atmospheric CO₂ concentrations are higher today than they have been over the last half-million years or longer.² The burning of fossil fuel globally releases about 5.5 billion tons per year into the atmosphere while deforestation contributes an estimated 1.6 billion tons per year. Measurements of atmospheric CO₂ levels since 1957 suggest that of the approximate total amount of 7.1 billion tons released per year by human activities, approximately 3.2 billion tons remain in the atmosphere, resulting in an increase in atmospheric CO₂. The balance is thought to be stored in the oceans and in the Earth's forested lands.³

The carbon cycle is operable within the lower atmosphere at a global scale. Emissions or sinks of carbon dioxide at any point on the planet contribute to the net concentration of the gas within the atmosphere.

Atmospheric GHG Concentrations

Over the past 150 years, CO₂ concentrations within the atmosphere have increased by 31 percent, methane by about 150 percent, and N₂O by 16 percent.⁴ Based on analysis of ice core data, today's atmospheric CO₂ concentration is the greatest in 420,000 years—and likely in 20 million years.⁵ From 1990 to 1999, CO₂, methane, and N₂O concentrations increased by 1.5 parts per million per year (annual increase of 0.4%), 7.0 parts per billion per year (annual increase of 0.5%), and 0.8 parts per billion per year (annual increase of 0.25%) respectively.⁶ The present methane concentration has not been exceeded during the past 420,000 years.⁷ The present N₂O concentration has not been exceeded during at least the past thousand years.⁸

As noted previously, changes in climate occur as a result of both internal variability within the system as well as natural and human-induced external factors. The influence of external factors on climate is

¹ US National Aeronautics and Space Administration. "Earth Observatory: The Carbon Cycle." Available at: http://earthobservatory.nasa.gov/Library/CarbonCycle/carbon_cycle.html

² Ibid.

³ Ibid.

⁴ Intergovernmental Panel on Climate Change. *Climate Change 2001: The Scientific Basis. A Contribution of Working Group I to the Third Assessment Report of the IPCC*, Cambridge, UK and New York, NY: Cambridge University Press, 2001.

⁵ IPCC. *Climate Change 2001: Synthesis Report*, 2001.

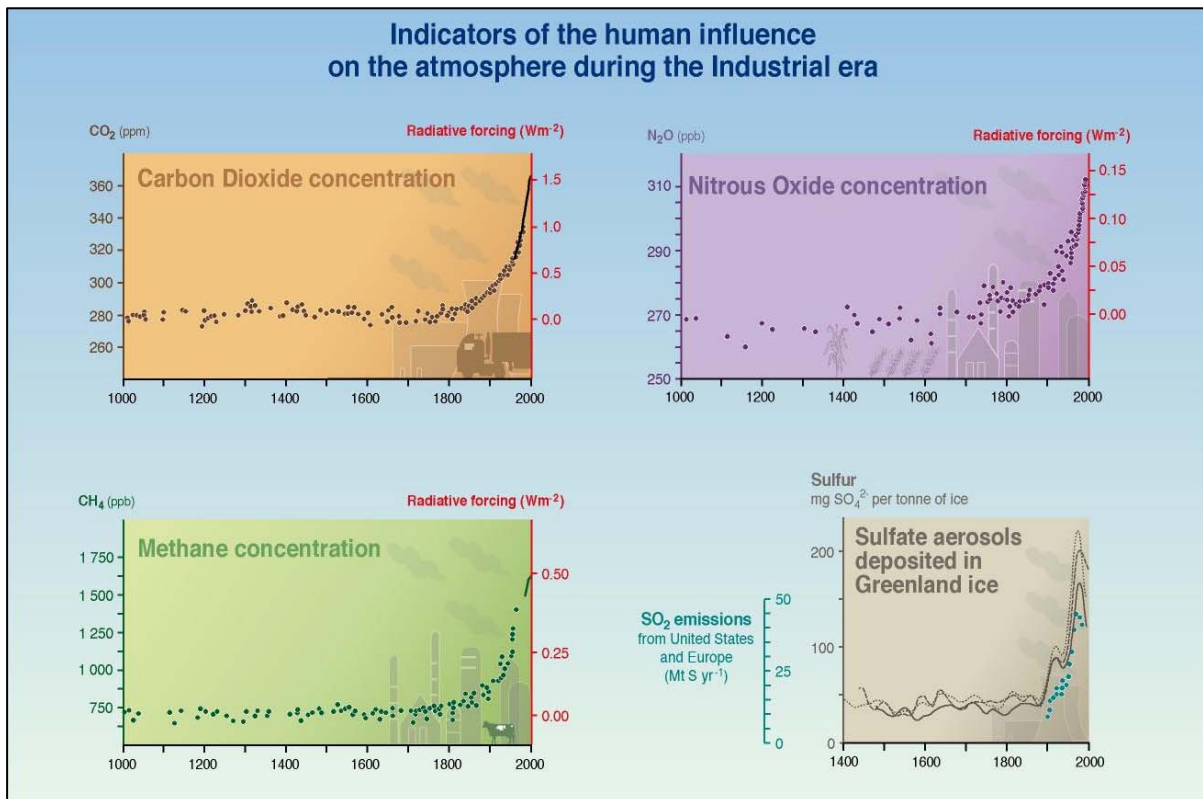
⁶ IPCC. *Climate Change 2001: The Scientific Basis*, 2001. op. cit.

⁷ Ibid.

⁸ Ibid.

measured in terms of radiative forcing. A positive radiative forcing, such as that produced by increasing concentrations of greenhouse gases, tends to warm the surface. A negative radiative forcing tends to cool the surface. Negative forcing from an increase in some types of microscopic airborne particles (aerosols) are thought to have an influence on current net radiative forcing of the Earth's climate system.⁹ The major sources of anthropogenic aerosols are fossil fuel and biomass burning. Aerosols vary considerably by region and respond quickly to changes in emissions. In addition to their direct radiative forcing, aerosols have an indirect radiative forcing through their effects on clouds. There is now more evidence for this indirect effect, which is negative, although of very uncertain magnitude. Figure 1 below illustrates trends in atmospheric concentrations over the last millennium.

Figure 1: Trends in Atmospheric concentrations of GHG and Sulfate Aerosols: 1000 – 2000 AD¹⁰



Trends in GHG Emissions

Individual greenhouse gases have differing radiative effects once emitted because of the differing lengths of times these gases remain in the atmosphere and how well each gas absorbs outgoing radiation. To normalize the effects of key greenhouse gases, each is indexed against CO₂ to determine its “global warming potential.” The global warming potentials for the six greenhouse gases addressed by the Kyoto Protocol are presented in the following table.¹¹

⁹ Ibid.

¹⁰ Ibid.

¹¹ Ibid.

Gas	Global Warming Potential*
Carbon dioxide (CO ₂)	1
Methane (CH ₄)	21
Nitrous Oxide (N ₂ O)	310
Hydrofluorocarbons (HFCs)	1,300 to 11,700
Perfluorocarbons (PFCs)	6,500 to 9,200
Sulfur hexafluoride (SF ₆)	23,900
* The Global Warming Potential is the ratio of the warming caused by a substance to the warming caused by the same mass of carbon dioxide. It is a relative scale. For example, methane has 21 times the warming potential of carbon dioxide. ¹²	

Carbon dioxide accounted for 84.7 percent of the nation’s greenhouse gas emissions in 2003.¹³ It results primarily from the combustion of fossil fuels used to produce electricity and to power motor vehicles as well as from a few industrial processes.¹⁴ Forestry and other land use activities in the U.S. remove more carbon from the atmosphere than they emit, resulting in net carbon storage, called “sequestration.” Methane released by landfills, coal mines, oil and gas systems, and agricultural activities accounted for 7.9 percent of the total U.S. greenhouse gas emissions in 2003.¹⁵ Nitrous oxide is emitted during agricultural and industrial activities, and during combustion of solid waste and fossil fuels. In 2003, it accounted for 5.5 percent of the national greenhouse gas emissions.¹⁶

According to the 2004 Department of Energy, Energy Information Administration report¹⁷, Florida ranks 5th in the nation for energy-related CO₂ emissions (based on energy usage). Of the total 238.8 million metric tons of carbon dioxide produced in Florida during 2001, the electric power and transportation sectors were responsible for over 90% of the emissions, respectively contributing 116.6 (49%) and 98.7 (41%) million metric tons. Florida’s 2001 fossil fuel CO₂ emissions represent approximately one tenth of one percent of the global fossil fuel emissions total of 24.121 million metric tons in the same year.¹⁸

Emissions of greenhouse gases are linked to economic activity and population. Trending with the economic expansion of the 1990s, greenhouse gas emissions in the U.S. have increased 17 percent between 1990 and 2003.¹⁹ However, U.S. greenhouse gases emitted per dollar of gross domestic product—or greenhouse gas intensity—decreased approximately 20 percent during this period.²⁰ Florida’s growth and subsequent increase in energy-related CO₂ emissions between 1990 and 2001 ranked 2nd among states with an addition of over 51.5 metric tons.

State	2001 Total CO ₂ Emissions (in million metric tons)
Texas	656.1
California	383.1
Pennsylvania	261.9
Ohio	252.3
Florida	238.8

¹² US EPA, Climate Change Information at www.epa.gov/climate

¹³ U.S. Environmental Protection Agency. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003*, EPA 430-R-05-003. Washington, DC: U.S. Environmental Protection Agency, Office of Atmospheric Programs, April 2005.

¹⁴ Ibid.

¹⁵ Ibid.

¹⁶ Ibid.

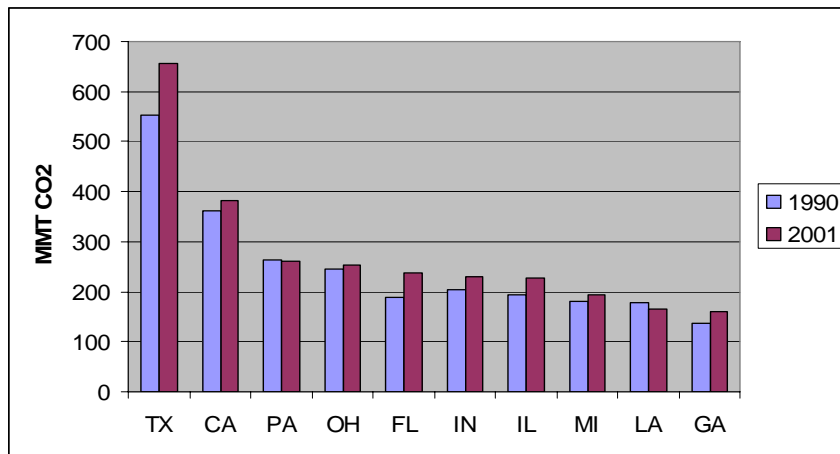
¹⁷ U.S. Energy Information Administration. *State Carbon Dioxide Emissions: 2004*. Available at: http://www.eia.doe.gov/oiaf/1605/ggrpt/pdf/appc_tbl2.pdf

¹⁸ U.S. Energy Information Administration. *International Emissions Data: Energy-Related Emissions Data, 2006*. Available at: <http://www.eia.doe.gov/pub/international/iealf/tableh1co2.xls>

¹⁹ U.S. EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2003*. op. cit.

²⁰ Ibid.

Figure 2: Change in state-level emissions of energy-related CO₂: 1990 - 2001



Total greenhouse gas emissions are partially offset by the natural uptake of carbon (carbon sequestration) in the growth of forests, urban greenspaces, and on agricultural lands. In 2003, 12 percent of total U.S. emissions were offset by sequestration.²¹ By subtracting sequestered carbon, national and state inventories can calculate net emissions. The total amount of carbon sequestered naturally within Florida is currently unknown, but can be reasonably assumed to represent a similar proportion to national offsets.

Effects of Climate Change

The global mean surface temperature of the Earth has increased by about 1° Fahrenheit since the late 19th century.²² The years between 1990 and 2001 include the eight warmest since systematic measurement of temperatures by instruments began about 120 years ago.²³ Scientists have been able to extend the understanding of climate change far beyond that period by examining “proxy” data. Proxy data include natural archives of climate information such as tree rings, ice cores, corals, and sediments. In addition, historical documents such as ships’ and farmers’ logs, travelers’ diaries, and newspaper accounts can provide insights into past weather and climate conditions. Proxy temperature reconstructions are more uncertain than direct instrumental measurements, and have been the subject of controversy. The so-called “hockey stick” reconstructions, named for their resemblance, were recently reviewed by the National Research Council of the National Academies of Science at the request of the Administration. The NRC found that the reconstructions indicate “with a high level of confidence” that global mean temperature was higher during the final decades of the 20th century than in any comparable period over the past four centuries.²⁴ Proxy data also indicate that the temperature in many, but not all localities within the last 25 years are “greater than at any time between 900AD and 1600AD.”²⁵ The National Research Council (NRC) further concluded that global mean temperature reconstructions based on data from periods earlier than 900AD are less reliable because of the scarcity of data from representative points around the planet and variances in how data were analyzed. The global mean temperature reconstruction for the past 1,000 years is presented in Figure 2.

²¹ Ibid.

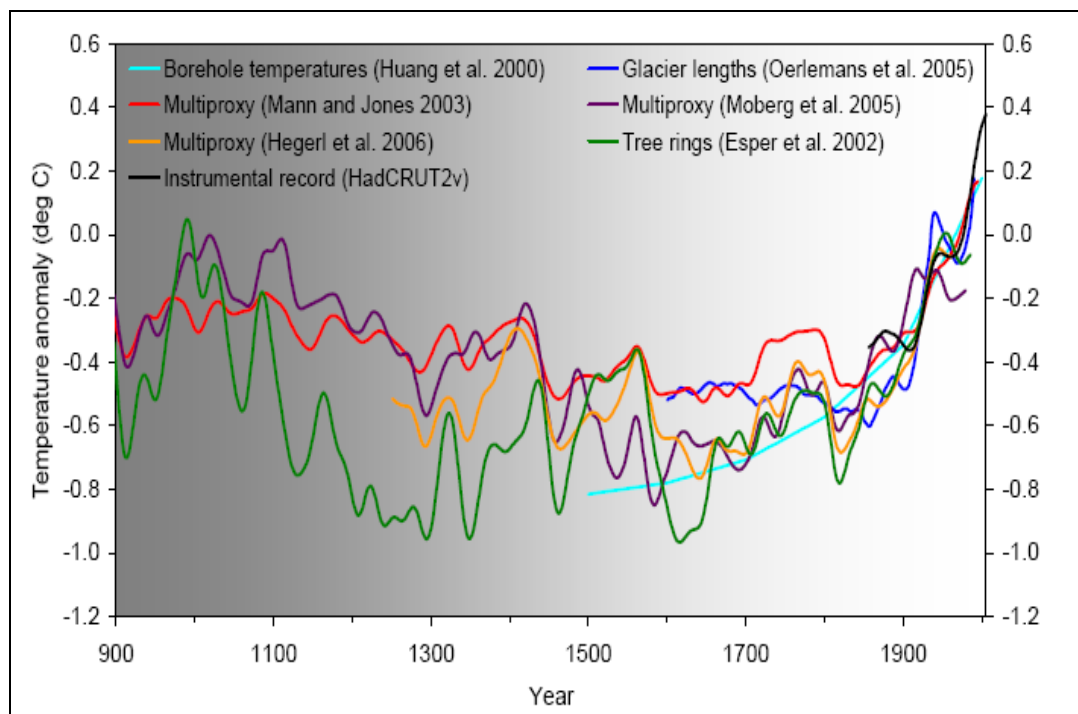
²² IPCC. *Climate Change 2001: The Scientific Basis*. *op cit*.

²³ Waple AM, JH Lawrimore, MS Halpert, et al. *Climate Assessment for 2001*. American Meteorological Society, 2002. Can be found at <http://lwf.ncdc.noaa.gov/oa/climate/research/2001/ann/annsum.pdf>

²⁴ *Surface Temperature Reconstructions for the Last 2,000 Years*. 2006. National Research Council.

²⁵ Ibid.

Figure 2: Reconstructions of average surface temperature of the Northern Hemisphere for the past 1,000 years



Global averages mask great regional variations; observed temperatures in some parts of the world have increased while other areas, temperatures have decreased. Many areas of the U.S. have warmed by more than 1°F, whereas the Southeast has cooled somewhat during the past century.²⁶ In some regions, particularly the Northeast, the Southwest, and the upper Midwest, the warming has been greater.²⁷ The increase in some places, such as the northern Great Plains, has reached as much as 3 °F.²⁸ During the 20th century, average U.S. temperatures dropped below freezing two fewer days per year than they did in the 19th century.²⁹

EFFECTS OF CLIMATE CHANGE IN FLORIDA

Climate change effects forecasting relies largely on global and regional models of the remarkably complex global climate system. The model results, while much improved in recent years by virtue of their ability to replicate past observed temperatures, still retain levels of uncertainty in projecting future global mean temperatures. Additional uncertainty is introduced when extrapolating global mean temperatures to address forecast effects such as sea level changes, rainfall patterns and impacts to

²⁶ Karl, TR, Knight RW, Easterling DR, Quayle RG. 1996. Indices of climate change for the United States. *Bulletin of the American Meteorological Society*, 77(2): 279-292.

²⁷ Ibid.

²⁸ Ibid.

²⁹ Easterling DR. 2002. Recent changes in frost days and the frost-free season in the United States. *Bulletin of the American Meteorological Society*, Sept: 1327-32.

ecosystems. Given these uncertainties however, some potential effects of global climate change that may be observed within Florida have been assessed.

Assuming continued growth in world greenhouse gas emissions, the modeling used by the 2000 National Assessment Synthesis Team of the U.S. Global Change Research Program suggested that average annual temperatures will increase by 5 to 9 °F by 2100.³⁰ The model results indicated that the Southeast would experience greater temperature increases than the nation as a whole with higher heat indexes (temperature plus humidity) of between 8 to 15 °F by the end of the current century.³¹ Specific effects of increased temperatures could include reduced air quality due to ground-level ozone (smog) formation, greater incidences of heat stress and related mortality among the elderly, and increased incidence of water-borne illnesses, toxic algal blooms, and seafood-borne *Vibrio vulnificus* outbreaks.³² Observed levels of sea level rise are expected to be between 18 and 20 inches along Florida coasts by 2100 which will result in the inundation of coastal areas, increased aquifer salinity, and alteration of Florida's estuaries.³³ Increased temperatures will impact the species composition and range within Florida's forests and natural areas.

³⁰ National Assessment Synthesis Team. *Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change*. Washington, DC: U.S. Global Change Research Program. 2000

³¹ Ibid.

³² U.S. EPA. *Climate Change and Florida*, EPA 230-F-97-008i. Washington, DC: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation, September 1997.

³³ Ibid.