Chapter 31.

Implications of Global Climate Change for Southern Forests: Can We Separate Fact from Fiction?

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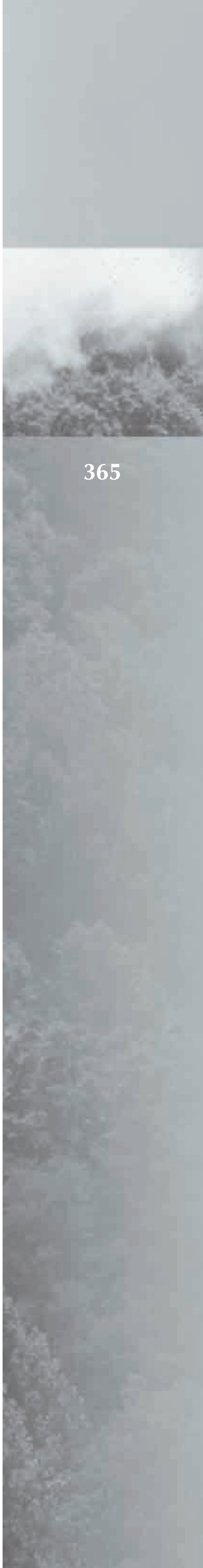
Abstract—*There is no scientific dispute regarding the existence of a greenhouse effect. There is no doubt that water vapor, carbon dioxide (CO_2), and methane concentrations are greenhouse gases. The data showing increases in CO_2 in the atmosphere are incontrovertible. Uncertainties arise when the Earth's biological responses to climate change are to be quantified. Such uncertainties can be compounded when the responses of ecosystems, especially forests, are to be delineated. Complex interactions among effects of climate change, disturbance, competition, invasive species, management intervention, land use change, and other actions must be clarified by modeling. Model development has improved greatly, but evaluation and validation remain difficult. Model outputs for the South show a fairly wide range of potential changes under scenarios developed from different climate models, suggesting that the assumption of steady-state conditions has little likelihood of occurrence. This implies that we should rethink management approaches, design research to include new ecosystem variables, and seek integrated ecosystem knowledge on scales heretofore rarely treated.*

INTRODUCTION

There is persistent skepticism about the evidence that greenhouse warming may be occurring, and this skepticism requires consideration. This chapter is a semitechnical discussion of the issues, and is designed to shed light on the question of climate change without attempting to present new research information or make new interpretations of the research findings.

There is no scientific dispute regarding the existence of a greenhouse effect in planetary atmospheres such as ours (Raval and Ramanathan 1989). Nor is there any doubt that water vapor, carbon dioxide (CO_2), and methane are greenhouse gases (Ledley and others 1999). Moreover, the data showing increases in atmospheric concentration of CO_2 are incontrovertible (Keeling and Whorf 1999, Keeling and others 1989). Lastly, it is clear that the rise in atmospheric CO_2 is largely attributable to the burning of fossil fuels (Andres and others 2000, Carbon Dioxide Information Analysis Center 2000). Does this prove that there will be climate change in the form of global warming? It strongly suggests a change in the Earth's energy balance, but there is no simple yes or no answer to the question about global warming, because the variables that affect the outcome are many, and the interactions between Earth system processes have not been delineated as fully as one might wish.

It is possible to make probabilistic estimates of likely outcomes, and these have been made (Harvey and others 1990, 1997). The Inter-governmental Panel on Climate Change (IPCC) is thought to be the most authoritative scientific body that has assembled such estimates. The acceptance of the IPCC estimates has not been total. Uncertainties remain, and skepticism persists. Because these estimates have vast policy implications, the debate has spilled from the purely scientific area into the arena of public



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debate and governmental policy. The controversy has led august scientific bodies to make strong statements regarding the status of climate change science. In this case a group of National Science Academies, representing 16 countries, say the following (excerpted from http://www.royalsoc.ac.uk/files/statfiles/document-138.pdf):

> The . . . IPCC represents the consensus of the international scientific community on climate change science . . . and we endorse its method of achieving this consensus. Despite increasing consensus on the science . . . doubts have been expressed . . . . We do not consider such doubts justified . . . . We support the IPCC's conclusion that it is at least 90 percent certain that temperatures will continue to rise, with average global surface temperature projected to increase by between 1.4 and 5.8 °C above 1990 levels by 2100 . . . . The balance of the scientific evidence demands effective steps now to avert damaging changes to the earth's climate.

This statement has since been endorsed by the National Academy of Sciences. Figure 31.1 shows the reconstructed temperature record for the past millennium and the recent temperature rise coincident with the era of industrial development.

CLIMATE CHANGE SKEPTICS

Despite the growing scientific consensus, skepticism continues, both in the strictly technical areas, where it is part of the scientific process, and also in the arena of policy development. It is useful to examine the scientific validity of the claims made by the skeptics. These claims have appeared in Web sites [2] [3] and in a book by Lomborg (1999) and can be summarized as follows:

- The present uncertainties in Earth processes overwhelm any confidence in predictions of future climate. The uncertainties might include modeling deficiencies, skewing of temperature records due to "heat island" effects, or the swamping of the small increases in CO_2 derived from fossil fuel compared to the large-scale exchange of CO_2 between the atmosphere and the oceans and land
- Factors other than increases in greenhouse gases are responsible for warming trends; e.g., Milankovich cycle, changes in the sun's energy output
- Radiometric data from satellites and high-altitude devices show no warming

Arguments made on scientific grounds are testable hypotheses, subject to confirmation or rejection. We also see arguments made on policy grounds, or derived from various logical positions, or, at times, logical fallacies. Examples of the latter include the use of the fallacy of "condemning the origin," e.g., climate change arguments are made only by "greens" or radical environmentalists; ergo, the argument must be false, or by discrediting the process ("the IPCC is a United Nations body, hence subject to political conspiracies"). Policy perspectives are not subject to scientific review, but can be examined in the light of precedents, and by examining the assumptions upon which they rest. For example, the argument has been made that expending national resources on mitigating potential climate change is unwise because of present uncertainties. One can investigate the underlying assumptions using Bayesian formal decision theory. Thus, it may be even more likely that the "no regrets" option, i.e., the avoidance of investments to mitigate climate change that will prove costly if no climate change occurs, is not the least expensive, given the risks. Of course, positions derived from self-interest, i.e., having a "personal" stake in the outcome, are not subject to scientific debate, because they bear no relation to the scientific process.

Consider the issue of scientific uncertainties. The IPCC contends that improvements in data collection and processing, model developments, process-level understanding, and improved large-scale consistency of models with observations give a confidence level of better than 90 percent for the statement that 20th-century global temperature increases are the highest of the last 1,000 years. Moreover, the likelihood that temperature increases of the 20th century are not due to climate variability is now estimated at the 99 percent level (Houghton and others 2001). Such convergence of the analysis demands a better scientific response than simple rejection of the climate change hypothesis on the grounds of uncertainty. Hence it is important to distinguish

[2] George C. Marshall Institute. 2002. Homepage. http://www.marshall.org. [Date accessed unknown].

[3] Heartland Institute. 2002. http://www.heartland.org. [Date accessed unknown].

between scientific debate about the implications of the remaining uncertainty, and categorical assertions that uncertainties are large. Moreover, improvements in process-level understanding have largely overcome the difficulty of calculating small differences between large numbers, and signals can be observed despite the large flux of CO_2 between atmosphere, oceans, and the land (Houghton and others 2001).

Factors other than increasing greenhouse gas concentrations in the atmosphere are affecting the total radiative energy reaching the Earth's envelope. Some factors work on cyclical scales far longer than any relevant to the postindustrial emissions era, while others, such as 11-year sunspot cycles, are too short to influence climate change but do confuse the signal (Houghton and others 1994, Lean and Rind 1996). Hansen (1998) asserts that the existing record of solar radiance observation shows variation on the order of 0.1 percent, which translates into a forcing of a few tenths of watts/m^2, whereas the forcing from CO_2 increase over preindustrial levels alone is about 1.4 watts/m^2 (Hansen 1998). The relevant observation is that secular changes are additive to the human-caused fossil fuel-derived effects, and that the total picture needs to be analyzed.

Local anomalies, such as the heat island effect, have been taken into account in the analysis of global surface temperature data. For example,

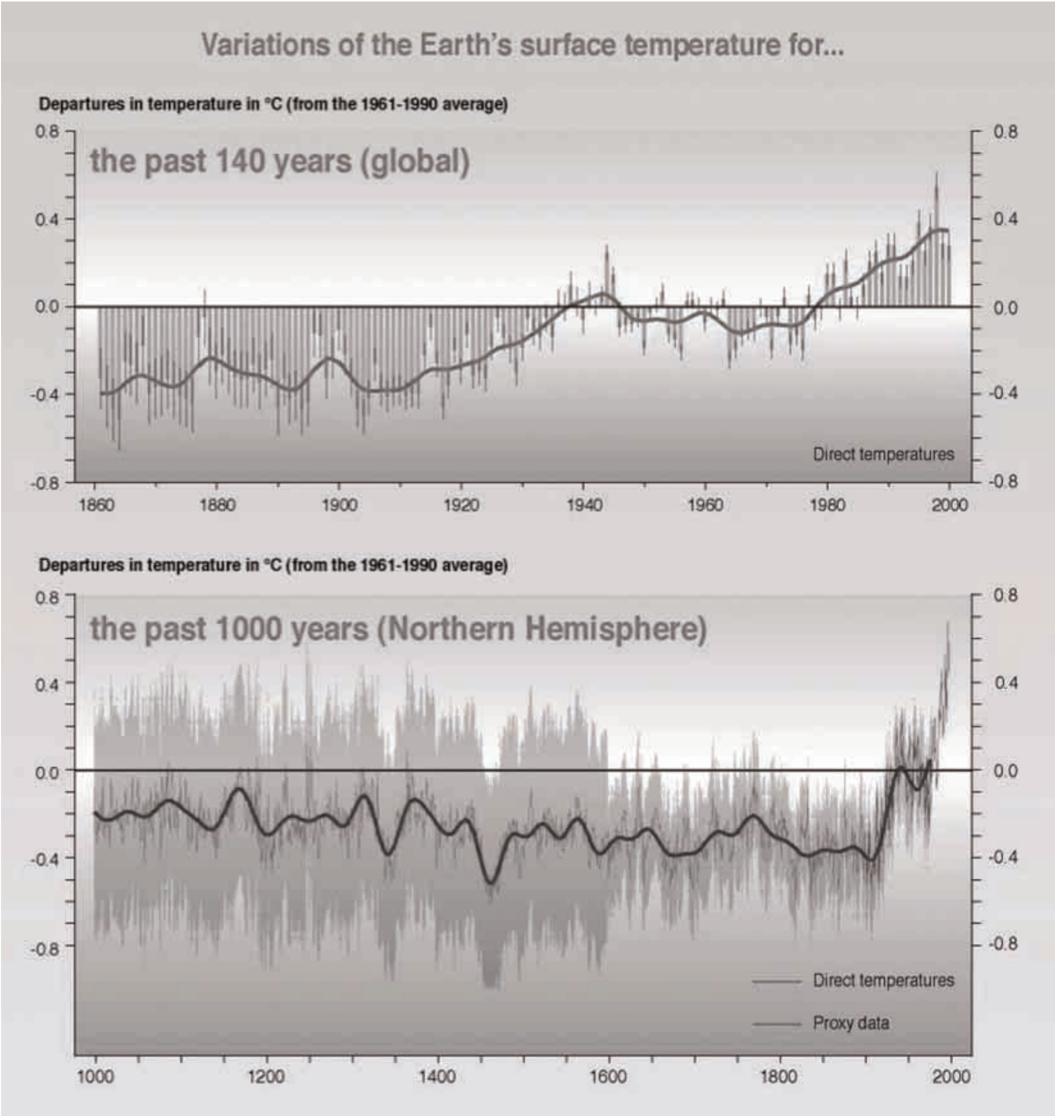

Figure 31.1—The reconstructed Earth surface air temperature record for the past millennium (http://www.ipcc.ch/present/graphics/2001syr/ppt/05.16.ppt).

Hansen and others (2002) point out that observed warming is greatest at high latitudes, especially in Northern Canada, Alaska, and parts of the Antarctic Continent. By comparison, the heat-island effect occurs primarily at middle latitudes where the greatest numbers of cities are located. Space-based observations see no stratospheric warming. This is consistent with thermodynamic principles, stratospheric cooling due to ozone depletion, and effects of sulfate aerosols (National Academy of Sciences 2001) and does not contradict ground-based observations (Houghton and others 2001).

The magnitude of uncertainties concerning the heat island effects and the scale of the corrections applied do not invalidate the record of recent rise in global surface temperature, but affect the absolute magnitude and its standard error. Similarly, upper air temperature measurements from balloons and aircraft do not invalidate present assessments. The argument is advanced that the greenhouse forcing from CO_2 increases is negligible compared to the exchange of this gas in the seasonal uptake and release from plant photosynthesis and respiration. This argument ignores both the physics of greenhouse gases and the principle of superposition. The latter that says as a first-order approximation the effects of multiple processes are additive; hence, the additional atmospheric loading of increasing CO_2 will be cumulative regardless of the magnitude of the annual exchanges.

It is important, therefore, to distinguish skepticism stemming from bad science or preconceived conclusion from scientific skepticism that seeks to ensure the knowledge derived is complete, accurate, and inclusive of all the important variables that are driving the system trajectory. Not all uncertainties have been eliminated, nor is the potential of unexpected future results negligible. This is particularly true when one attempts to map the responses of terrestrial vegetation to probable external forcing, and even more so when one wants to examine effects at local to regional scales.

IMPLICATIONS FOR SOUTHERN FORESTS

What, then, are the implications of global climate change for the Southern United States in general, and for its forests in particular?

The most important inference is that the continuation of the present climate is no longer the only tenable scenario. Instead we are faced with a range of scenarios that may have differing probabilities attached to them but cannot be dismissed out of hand. These scenarios arise principally from two processes. One derives from the uncertainties regarding future CO_2 and other greenhouse gas emissions, and the other from differences in the climate models themselves, which have been evolving to incorporate a greater number of variables and feedback loops over time. Models have been built that map potential vegetation based on climate drivers including temperature, such as growing degree days and winter temperature minimums, water (precipitation and soil moisture holding capacity), and photosynthetic radiation. These can use the outputs of general circulation models (GCM) to drive the vegetation both in equilibrium phase, i.e., after atmospheric CO_2 has doubled and equilibrium is attained, and in dynamic phase, mapping the vegetation response to gradually changing climate (e.g., Bachelet and others 2001, VEMAP members 1995). Building in the responses of the terrestrial ecosystems via their biogeochemical cycles is still a developing area (National Academy of Sciences 2001).

As a result, major GCMs exhibit a range of possible climate change outcomes, especially at the regional scale, where the remaining uncertainties are perhaps greatest. It is instructive to consider the worst-case scenarios along with the benign or even desirable outcomes.

A scenario that might pose particular difficulty, because it might convey a false sense of security, is one in which climate change would initially be favorable, i.e., one with initial warming and steady or increasing precipitation, followed by the development of unfavorable conditions, i.e., continued warming accompanied by increasing aridity. A hypothesis that may apply for the Southern United States is the expansion of the subtropical high-pressure fields, including the Bermuda High (Bachelet and others 2001, Doherty and Mearns 1999). Such expansion would shift portions of the jet stream northward, which might unfavorably alter the precipitation and water regime. Southeastern forests would presumably decline, and catastrophic fire could well be the change agent for this decline.

For the Southern United States, ramifications of such scenarios go beyond forest responses, and include changes in water availability among other hydrologic effects. One may use the global climate models to calculate ground-water balance and river discharge, which together can describe water

availability. Figure 31.2 is a depiction of the water availability under the scenario of a drier South onto which population growth rates have been superimposed. The figure shows water stress as the ratio of changed availability divided by changed growth rates. This is only one possible outcome of several, selected to show a worst-case situation. There are benign and even promising scenarios in which forest expansion is a strong possibility. Unfortunately, there are no reliable data at this time on the probability of occurrence for any of these scenarios (see discussion in Smith and others 2002).

The foregoing implies that our management strategies with respect to climate change must be structured to function in the context of uncertainty and incomplete information. This is not shocking and not unprecedented; a similar situation exists with respect to other phenomena, such as market fluctuations or exposure to risk from hurricanes and floods. It simply means that decision theory approaches developed elsewhere may be applied here and that risk assessment and risk management approaches apply in this arena as they do in others (Gucinski and McKelvey 1992).

Risk assessment must address two elements, the probability of the occurrence of an event, such as future drought, and significance (or "value" or "utility" in economics parlance) of the event when it does occur. For large-scale events with costly or even catastrophic outcomes, it has been customary to take a "risk-averse" stance over a "risk-neutral" one, but even that can be problematic in terms of required action. The "zero-infinity" paradox, in which the probability of the occurrence of an event is vanishingly small, but the consequences simply catastrophic, such as unprecedented wildfire, or a massive earthquake in an urban area, requires preparatory action regardless of likelihood.

What are the implications of potential climate change for risk management?

The study of disturbance processes, and their lessening or accentuation by changing climate, is still relatively young. Wildfire frequency and intensity is being modeled as a response to the effects of climate change on forest ecosystems (Lenihan and others 1998). McNulty (2002) has described effects of hurricane on southern forests. Management strategies for resistance to hurricanes include planting (or encouraged regeneration) of deeper rooted and salt-tolerant species, and denser forest stocking (or lower thinning levels). On the other hand, management strategies for southern forest response to fire include removal of understory, planting (or encouraged regeneration) of species that are more fire resistant, and lower stocking—or higher thinning levels. It appears that improved forest management and better policy is also needed to improve postfire and posthurricane salvage.

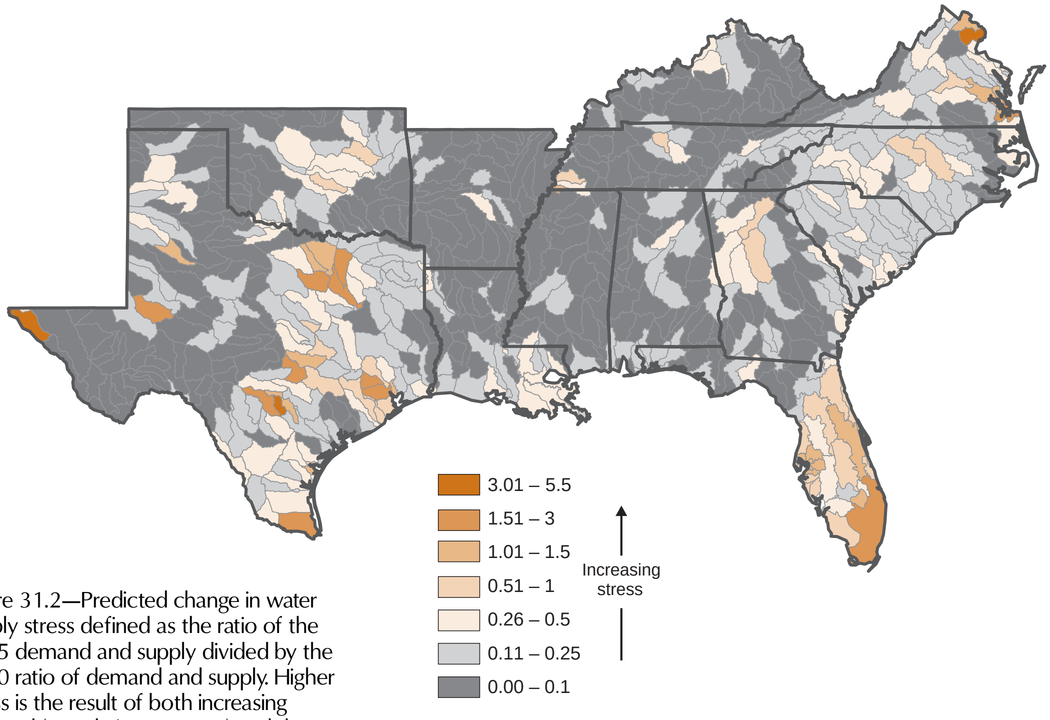

Figure 31.2—Predicted change in water supply stress defined as the ratio of the 2025 demand and supply divided by the 1990 ratio of demand and supply. Higher stress is the result of both increasing demand (population pressure) and the changed supply (climate driven) (McNulty and others 2004).

However, increased stocking needed for improved hurricane resistance increases fuel loads and is detrimental to fire suppression.

Potential effects of climate change on opportunistic species, especially invasives, are being studied, as are fragmentation-related barriers to plant migration, limits on seed, disruption of pollinators, and other potential problems. The better we understand the many facets of the possible responses to potential climate change, the better our position to weigh courses of action that remain open.

We believe that the following may serve as useful starting points for further exploration of possible options for mitigating negative climate change impacts on Southern U.S. forests:

- Manage forests for low-probability climate scenarios that have large-scale consequences. In this case, diversity may bring resiliency, and ultimately sustainability. This strategy may be especially appropriate for the Southern United States, where the rotation period for reaching harvest potential is relatively short
- Weigh the risks of omission against those of commission. Sometimes the risks incurred through inaction are greater than by implementing active approaches early, especially when these approaches would be beneficial regardless of the effects of impending climate change
- Analyze the potential cost of delaying action in the hope of obtaining better information when the delay may eliminate viable options. This is the argument advanced by the National Academies in endorsing the IPCC findings. Delaying action until there is greater certainty about the potential effects of climate change may have its own costs. Of course, this does mean that additional information should not be sought or consulted
- Be aware that risk assessment is influenced by both objective and subjective elements, and that consistency in assessment approaches will improve our chances of meeting our objectives

CONCLUSIONS

Approaches in which potential global climate change is treated as a set of future risks have often been ignored, and certainly have not been used adequately to assess possible impacts in the Southern United States. The existence of decision-theory frameworks, and their use in other sectors, makes this a viable option for managers, who can also benefit from additional research in the science community. If by improving our understanding of the risk spectrum now and applying the insights gained in the planning process, we may have many more options in the near term. Future climate change constraints may limit the choices for climate change mitigation considerably.

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