

The Development and Use of Climate Models for Understanding Future Trends of Water Availability in the West

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The most recent IPCC assessment has convinced most climate scientists that humankind is changing the earth's climate and that significant global warming is taking place. A brief review of the development and use of climate models will be presented and compared with 20th century observations. These computer simulations have been extended into the 21st century and beyond. A description of what is in climate models will be given with an emphasis on the how they can provide insights to future water availability. If the world policymakers decide to shift from a business-as-usual fossil fuel energy strategy to increased conservation, renewables, and possibly nuclear, we have computer simulations of predicted future climate change from such low carbon emission scenarios. Finally, at the end there will be a discussion of the scientific uncertainties along with an analysis of policy options including possible geoengineering of the climate system.

Look Backwards to Plan for the Future?

Dr. Connie Woodhouse
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The current climate is being impacted by human activities to a degree that has not occurred in the past, and consequently, the climate of the past will not be analogous to the climate of the future. However, understanding the past climate can provide insights on what may be expected in the future. Tree-ring based reconstructions of hydrology provide information about a broader range of variability and extremes than provided by gage records alone, allowing recent climate trends and events to be assessed in a long-term context. Water managers in Colorado and Arizona are using a variety of strategies to incorporate the centuries-long records of hydrologic variability from these reconstructions into drought and resource planning in ways that may also be useful to Texas planners.

Downscaling for Assessing Climate Impacts: Examples and Future Directions

Dr. Ruby Leung
Laboratory Fellow
Climate Physics, Pacific Northwest National Laboratories

Climate varies across a wide range of temporal and spatial scales. Regional climate models have been used as a downscaling tool to study regional climate processes and provide regional climate information for assessing climate impacts. I will discuss the need and approach to regional climate modeling and provide examples of regional modeling studies relevant to assessing changes in the hydrological cycle and water resources.

Assessing Regional Climate Change Impacts

Katharine Hayhoe
Professor
Department of Geosciences, Texas Tech University

Regional climate change impacts studies are increasingly viewed as essential to informing sound decision-making in water management and related areas. A number of recent assessments - for California, the Northeast, and the Great Lakes - have played critical roles in motivating and supporting state policy initiatives and management decisions in those regions. Drawing on experiences with these assessments, I will present recommendations for design of relevant climate impact assessments, and summarize available information for Texas.

Climate Change/Water Resource Adaptation Options for Texas

Kathy Jacobs
Executive Director
Arizona Water Institute

Impacts of climate change are already visible and significant in the water sector. Much public attention has been focused on mitigation, but there has been little discussion on adaptation investments that are needed to limit vulnerability to drought and extreme events. There are many no-regrets strategies that can be implemented in Texas, including new approaches to monitoring, drought planning, conjunctive management, and use of climate information to develop forecasts at multiple scales in space and time.

Climate, Water, and Ecosystems: A Future of Surprises

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Complex Systems Research Center
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The aim of this presentation is to explore the possibilities and consequences of future interactions among climate, water, and ecosystems in Texas. We focus on the urgent need for usable science that can assist decision makers in anticipating and learning from unintended consequences of changes in land management. A case study of sorghum production in Hidalgo County is used to illustrate the complexity of soil-water-plant-climate interactions. Our preliminary assessment demonstrates the power of a biogeochemical model to inform land management decision making.

Uncertainties, unclear signals, and long time scales are characteristic of climate, water, and ecosystem interactions. We argue that there is a strong rationale for enhanced policy flexibility and innovation using a portfolio of reactive, adaptive, and precautionary land management strategies. Adaptive approaches to land management will become increasingly important in the more crowded and warmer world of the 21st century.

Climate Change and Texas Water: An Economic Investigation

Dr. Bruce McCarl
Regents Professor
Agricultural Economics at Texas A&M University

Forces likely to affect future Texas irrigated cropping are reviewed. Then results are given on the effects of climate change in Texas relative to the US and in the Edwards Aquifer region. Results show Texas is quite sensitive both in the profitability of irrigated agriculture and in the cost of environmental protection.

The Uncertainty Argument in the Climate Change Debate

Dr. Andrew Dessler
Professor
Department of Atmospheric Science, Texas A&M University

Over the last few decades, starting with the debate over the regulation of tobacco, a strategy to promote gridlock has been developed and used effectively in several policy debates. The strategy is to basically argue that the science is too uncertain to take action, which is actually not a scientific but a normative judgment. In this talk, I will discuss this "uncertainty" argument and how it is used in the climate change debate.

***Impacts of Climate Change on Biodiversity and Human Health:
From Global to Local***

Dr. Camille Parmesan
Associate Professor, Integrative Biology
University of Texas at Austin

Anthropogenic global warming has affected plants and animals around the world. Changes in timing of life events and in where species live have been seen on the land and in the water, in every ocean and on every continent. As extreme temperature and precipitation events have become more frequent, plants and animals are not only shifting pole ward and up mountains, but the most sensitive species and systems are dying out. Much of the unique biodiversity in Texas is related to karst and spring systems, both of which are vulnerable to changes in the timing and pattern of rainfall. Human health is not immune to these changes. The World Health Organization has already seen a rise in climate-related diseases and deaths, many related to changes in extreme precipitation. Floods and droughts directly increase mortality, as well as causing increases in water-borne diseases. Although we don't have many long-term datasets for Texas, well-documented global patterns of biodiversity and health impacts can be used to infer consequences for Texas.

How Will Texas Be Able Transfer Water Among Users After Climate Change?

Dr. David Eaton
Professor
LBJ School of Public Affairs, UT at Austin

Texas systems of surface water allocation are based on the historic hydrology of surface sources and the order and times proposed by stakeholder to withdraw water from those sources, subject to adjudications in some surface river basins. Texas groundwater allocation rules reflect a modified 'rule of capture,' subject to waste limits, groundwater district rules, as well as legislative and judicial fiat. Some analyst believe that climate change could affect precipitation in Texas and lead to conflicts over water rights, both **within** particular basins where legitimate demand exceeds supplies or **among** basins, where one basin could have reduced supplies and another enhanced supplies. One challenge to water management in Texas is how to cope with the legal, regulatory, economic, social and perceptual conflicts among users if future water availability differs from historical patterns. This paper discusses methods to prevent disputes but permit a large number of users to accommodate voluntarily water shifts or transfer among users and among basins. The approach uses methods such as water narratives, hydrologic models, and economic evaluation. It is based on open, transparent, and joint multi-user assessment of options to reach voluntary accommodations. This approach has been used successfully to reduce in advance potential disputes among water users in the Colorado River and Brazos River basins as part of Texas first successful inter-basin transfer. This paper identifies steps appropriate to address the uncertainties, risks, perceptions and frustrations among users stakeholders to shifts in how users have access to water. The paper reports results and outcomes from the Colorado-Brazos transfer under HB 1437.

The Changing Climate of South Texas 1900-2100

Dr. James Norwine
Regents Professor of Geography
Texas A&M Kingsville

Models suggest that subtropical locations will mainly be negatively impacted by twentieth-century global-warming-related climate change. The existing semi-arid subtropical South Texas climate, already problematic, is likely to become considerably more so by the end of this century. This could prove to be the region's greatest challenge since its first human inhabitants arrive ten or so millennia ago. Our new book, *The Changing Climate of South Texas 1900-2100: Problems and Perspectives, Impacts and Implications* (Norwine and John, eds., December 2007), the work of leading scientists and engineers, was prepared to provide citizens and leaders with knowledge in the form of a readable state-of-the-science assessment of what we know and where we are headed. Our job as we saw it was to describe and explain this new regional challenge to the best of our ability. We hope and believe that this work offers a "come and take it" challenge to other climate-vulnerable regions as an example to build and improve upon.

What Does the Historic Climate Record in Texas Say About Future Climate Change?

Dr. John Nielsen – Gammon
State Climatologist
Texas A&M University

The climate in Texas, as elsewhere in the world, is not a constant and is certain to continue to change. What does historical climate data say about past climate change in Texas? How reliable is this information? Has past Texas climate been a microcosm of global-scale changes, or has Texas climate gone its own way? Are recent changes consistent with projected future changes? How large are past changes compared to future projections? This talk will address these questions through analysis of the local portion of the United States Historical Climatology Network. The historical temperature measurements indicate a consistent pattern across Texas, with generally warm conditions during the early part of the 20th century through the drought years of the early 1950s, substantial cooling to the end of the 1970s, and substantial warming thereafter. Overall, the change in temperature since the beginning of the 20th century is smaller in Texas than the global average, but recent temperature changes have been more rapid locally than globally. Known or possible reasons for these differences include the expected large-scale pattern of temperature change, the influence of variations in sea surface temperature patterns, and the effect of local changes in land use such as irrigation and urbanization. The historical precipitation measurements indicate a remarkably steady increase in precipitation across the state of as much as several inches per year. Droughts were much more common throughout the state of Texas 50-100 years ago than more recently. This increase of precipitation contrasts with the future projected decrease of precipitation throughout the state according to simulations of global climate. It is possible that the rising precipitation is part of a natural cycle that would be expected to eventually reverse itself, leading to more severe droughts and greater water shortages in the future. It is also possible that any natural changes will soon be overwhelmed by the changes projected by global climate models, which would also imply more severe droughts and greater water shortages in the future. Finally, it is possible that the increasing precipitation is being caused by other influences, such as land use changes, changes in atmospheric aerosol content, and so forth, in which case a confident future projection must include an explanation of past precipitation changes. In any case, it is clear that droughts more severe than those experienced recently are part of the natural climate history of Texas.

Southwestern Drought – How Bad In the Past and What Does It Mean for the Future?

Dr. Malcolm Cleaveland
Professor
Department of Geosciences
University of Arkansas

Much longer records of drought than those available from meteorological observations can be inferred from tree-ring proxies of climate. Three mega-droughts identified in the western United States in the 14th, 15th and 16th centuries probably exceeded the 1950s drought in intensity and/or duration. In addition, Richard Seager et al. (2007) forecasts that droughts like the 1950s or the 1999-2004 episode will become the normal condition. It is certainly possible that this transition to a drier climate will increase the likelihood of occurrence of another mega-drought.

Spatio-temporal Changes of Rainfall and Temperature and Their Impact on Water Resources in Texas

Dr. Vijay Singh
Professor
Civil and Environmental Engineering
Texas A&M University

Research on climate change reported in recent years has led to the conclusion that climate has always changed irregularly at all time scales. Climate changes are closely perceived in terms of changes in hydrometeorological variables, such as rainfall, temperature, but these changes may not be consistent with the changing character of climate. In this discussion, we examine spatio-temporal changes of precipitation and temperature in Texas at different time scales (e.g., daily, monthly, seasonal, and annual), and evaluate the impact of these changes on Texas water resources, especially streamflow. We also evaluate the impact on droughts. This leads us to comment on the variability of water resources in Texas.

Sea-Level Rise and Coastal Wetlands Impacts

Dr. James Morris
Director
Belle W. Baruch Institute for Marine and Coastal Sciences
University of South Carolina

This talk summarizes the biogeomorphological response of coastal wetlands to sea-level rise (SLR). Coastal wetlands provide valuable ecosystem services, including the provision of habitat for commercially important biological resources and partial protection from storm surge. In response to rising sea level, coastal wetlands trap sediment and rise, and they transgress inland, at least until they meet topographic barriers. Their ability to rise in equilibrium with sea level is critical to maintaining total wetland area and ecosystem services. The equilibrium depends on the rate of sea-level rise (SLR) and the availability of sediment. As the rate of SLR increases, the equilibrium elevation will decrease. The vegetation will maintain this equilibrium until the elevation declines beyond a tipping point. The tipping point is the elevation that supports maximum vegetation growth and depends on the tidal range. Beyond the tipping point, the elevation will decrease quickly to a level that may fall below the lower vertical limit for the vegetation, and the wetland will transition to tidal mudflat or subtidal habitat. Regions such as the Gulf Coast that are microtidal, i.e. those with small tidal ranges, are far more sensitive to SLR than areas with larger tidal ranges.

The future of SLR is likely to be dominated by the loss of glaciers in Greenland and Antarctica, yet the most recent IPCC estimates of SLR (0.23-0.51 cm/yr) do not account for glacial melt because of the weakness of current models. The current rate of melting is unprecedented in modern history. For example, the ice covering the Arctic Ocean shrank to its smallest size in a century during the summer of 2007. This ice field does not contribute to sea-level rise because it floats, but it is a good proxy for the change occurring in ice fields grounded on land. The latest sea level data, including new measurements from satellites, shows acceleration in the rate of SLR, but due to long-period sea-level cycles, alternative explanations are possible. Long-term data from the NOAA Galveston tide gage shows that relative mean sea level on the Gulf Coast has increased 80 cm in the last century (0.8 cm/yr). By incorporating empirical data on ice melting, Rahmstorf (2007) concluded that sea level could rise 0.5-1.4 meters above the 1990 level by 2100. Thus, one can expect about 1-2 cm/yr along the Gulf Coast. Projections of a 1 m rise in sea level along the Gulf Coast indicate that significant flooding would occur. Current beach management rules in Texas are favor removal of structures from beaches and setbacks for new construction behind the limit of vegetation. However, this policy will not limit the displacement of coastal development in the future. In addition, coastal managers should establish set back requirements that allow for wetland transgression.

Wetland Vulnerability to Climate Change

Dr. Robert Twilley
Director
Department of Oceanography and Coastal Science
Louisiana State University

The wetlands of the U.S. Gulf Coast provide services that are significant to the quality of life in the region, help sustain the national economy, and help protect life and property from climate extremes. Some regions of the Gulf Coast, such as the Mississippi River Delta and Florida Everglades, are experiencing some of the highest wetland loss rates in the US, largely due to modifications to regional watersheds and coastal landscapes. Such modifications increase the vulnerability of these wetlands to future climate variability and change. Sustainable restoration of Gulf Coast wetlands requires planning for a future climate by returning critical water resources to the coastal landscapes to levels encountered when humans began modifying this region three centuries ago. Degradation of coastal wetlands through land development and water management reduces the capacity of wetlands to provide significant ecosystem services that are critical to reducing risks of living and working in coastal landscapes. Human activities intended to reduce damage to life and property from climate extremes has unintentionally increased the vulnerability of coastal areas to climate change by altering the natural hydrologic functions of wetlands. For coastal wetlands to be sustained in a changing climate, therefore, restoration planning must account for the consequences of both climate change and human engineering of the environment.

Wetland vulnerability to climate change is based on the ability of wetland systems to cope with varying rates of environmental change. With capacity for adaptation already reduced by human activities, additional climatic changes have important implications for wetland sustainability. Many coastal restoration projects proposed for the Mississippi River delta and the Everglades are predicated on returning many ecosystem functions to natural wetlands. Modification of river management systems in both Everglades and Mississippi River is under consideration as a way to increase freshwater and sediment supply, respectively, to promote wetland development. However, wetland vulnerability to present conditions has provided the traditional context for restoration planning; this context is insufficient to assure wetland sustainability over the century-long lifetime of major restoration efforts in the face of projected sea-level rise and hurricane intensification. Forward-looking measures are required to ensure that the necessary water resources will be restored to allow wetlands to build soil sufficient to survive a changing climate. There is still time to plan and execute large-scale coastal restoration projects for the Everglades and Mississippi delta that would be sustainable against projected climate change through the twenty-first century. The long-term sustainability of coastal wetlands will have to be re-evaluated over time as coastal systems respond to restoration measures. Ultimately, sea-level rise will continue for centuries after human-induced greenhouse gases are stabilized in the atmosphere. Wetland values to society can only be secured by accounting for long-term effects of climate change in designing near-term restoration projects.

***Biological response to changes in climate patterns: Gray snapper (Lutjanus griseus L.)
population explosion in Texas bays and estuaries***

Dr. James Tolan
Coastal Fisheries Ecologist
TPWD

The exponential increase in the abundance of gray snapper (*Lutjanus griseus*) populations in Texas bays and estuaries over the past 30 years can be related to increased wintertime surface water temperatures resulting from changing climate patterns. Trends in their relative abundance are evaluated using monthly fishery-independent monitoring data from each of the seven major estuaries along the Texas coast from 1982 to 2006. Environmental conditions demonstrate rising annual sea surface temperatures, although this increase is not uniform, with the largest proportion attributed to rising winter temperatures minimums since 1993. Positive phases of the North Atlantic Oscillation, resulting in wetter, warmer winters all along the eastern United States, have occurred nearly uninterrupted since the late 1970s. Increases in gray snapper abundance during this same time are linked to favorable over-wintering conditions for the newly settled juveniles, with increased recruitment success. In the absence of cold winters, this species has established semi-permanent populations in nearly every estuary on the Texas coast. A back-shift to negative phases of the North Atlantic Oscillation will likely result in returns to colder wintertime temperature minimums and this could topple these recent population gains.

***Planning for the Future of the Gulf Coast: Climate Change, Coastal Change, Community
Change***

Dr. Denise Reed
Coastal Geomorphologist
University of New Orleans

21st century changes in atmospheric, riverine and marine forcing have major implications for the low-lying coasts of the Gulf coast. The response of coastal wetlands, for example, depends greatly on the interactions of freshwater supply, temperature changes, and sediment availability. Beaches and barrier systems will be affected by rising sea-levels and future storms, but also by the response of dune vegetation. Options exist for society to enable coastal systems to adapt and change in the face of climate change. This presentation will explore ways in which coastal communities and other users adapt their own activities to give coastal systems a fighting chance in the future.

Climate Change, Growth, and Managing the Edwards Aquifer

Dr. Hugo Loaiciga
Professor
Department of Geography
University of California at Santa Barbara

This lecture will present estimates of the probable effects of doubling of atmospheric CO₂ on recharge in the Edwards Aquifer, Texas. It will also review the uncertainties besetting such estimates and dwell into the relative impacts of recharge change and population growth on the Edwards Aquifer management over the next half century.

Climate Change, the Edwards Aquifer, and the Endangered Aquatic Salamanders of Barton Springs, Austin, Texas

Dr. Laurie Dries
Watershed Scientist
City of Austin

The Edwards Aquifer is a limestone groundwater system that harbors some of the greatest diversity of karst inhabiting species. Many are endangered or rare aquatic species found in the numerous springs scattered through this aquifer, and include both subterranean and epigeal dwellers. One of those species is the federally endangered Barton Springs Salamander, *Eurycea sosorum*, whose only habitat is the four springs known as Barton Springs within the City of Austin, Texas. For this and similar species, the quantity and quality of the water emanating from the springs is critical to avoidance of extinction, yet there is increasing demand for up-gradient removal of groundwater from the Edwards Aquifer to support growing human populations in the cities of Central Texas. Rainfall patterns are intimately related to the cyclical fluctuations in quantity of groundwater. Thus, historical rainfall and spring discharge data are often used to predict future patterns in quantities of water, and occurrence and frequency of drought. These predicted patterns are then used to develop regulatory policies regarding allowable removal of groundwater for human purposes. Changes in climate that produce deviations from the predicted effects can alter the ecology of springs and fate of the inhabitants in unforeseen ways, and render some regulatory efforts ineffective. Given a degree of uncertainty around any predicted effect of climate change, it is important to consider whether it is better to be over-cautious or over-confident, because some predictions, if incorrect, can have irreversible consequences.

Will Climate Change Affect the Aquifers of Texas?

Dr. Robert Mace
Hydrogeologist
Texas Water Development Board

The effects of climate change on the groundwater resources of Texas will depend on the geology, recharge processes, and pumping in the state's aquifers. Highly permeable aquifers such as the Edwards Aquifer will be the most affected by any climate change. Other aquifers, because of how they recharge, are not likely to be greatly affected by changes in the climate; however, they will be affected by any climate-induced changes in pumping.

The Economic Value of Resources to Sustain Nature and Ecosystem Services

Dr. David Yoskowitz
Associate Professor
Harte Research Institute & College of Business, Texas A&M University – Corpus Christi

Efforts are underway to demonstrate the intangible but real economic value provided by the natural environment in Texas. To inform decision-making about a particular resource it is critical to better understand the link between resource protection, ecosystem health, and the economic value of the resource in question. Using innovative applications of a variety of economic techniques it is possible to provide an economic representation of the ecosystem in decisions about natural resource management.

The proposed presentation will provide an overview of the principles of non-market valuation of natural resources and the ecosystem services they provide. Practical applications of how valuation can inform policy-making will be highlighted. Case studies of valuing freshwater inflows into the Rio Grande estuary and San Antonio Bay will be provided. Examples of how valuation techniques can also be applied to examining climate change issues and mitigation strategies will be discussed.

California Water Management: Subject to Change

J. T. Andrew
Executive Manager for Climate Change
California Department of Water Resources

As a member of Governor Schwarzenegger's Climate Action Team, the California Department of Water Resources (DWR) is taking a dual approach to fighting global climate change: *mitigation*, the reduction of energy and greenhouse gas emissions related to water use, and *adaptation*, changing culture and infrastructure to adapt to global warming. Overall, along with a new model for statewide water management systems, DWR recommends local and regional water managers implement a portfolio approach for water resources.

***Realistic Approaches to Deal with Climate Change Impacts on Water Resources
Management and Policy***

Dr. Ken Rainwater
Professor
Department of Civil Engineering, Texas Tech University

Professionals in water resources planning, whether they be engineers, scientists, regulators, treatment plant operators, or politicians, are now called on to demonstrate that their work accounts for present and future climate change impacts. Even though those predicted impacts are uncertain, some entities must make financial decisions for planning horizons of several decades. This presentation explores the differences in the management choices that can be made on both the supply and demand sides of water resources issues. For example, on the supply side, many municipalities already have or plan access to multiple water sources with various raw quality and potable treatment needs. On the demand side, some municipalities already have policies to limit demand through rate structures and conservation measures. Agricultural and industrial water consumers often have fewer choices of local supply and must set reasonable production goals based on the availability and costs of all their inputs, including water. Uncertainties due to projected growth and sustainability issues will also be compared.

***Do Citizens Link Climate Change to Future Water Availability:
Implications for Policy Support***

Dr. Arnold Vedlitz
Director
Institute for Science, Technology, and Public Policy
George Bush School of Government and Public Service

The speech will discuss results of a recent public opinion poll of Texas citizens regarding their levels of awareness of drought, the relationship of climate change to drought events and their resulting support or opposition to various drought policy choices for adaptations.