Water Forum III: Droughts and Other Extreme Weather Events
October 14–15, 2013

ABSTRACTS

The Center for Integrated Earth System Science (CIESS) hosts the third annual drought symposium, Water Forum III: Droughts and Other Extreme Weather Events, on October 14–15, 2013 with a focus on the latest research and provide a forum for discussion of trends, problems and future directions. While the papers are primarily concentrated on droughts in Texas, other extreme weather events or those occurring elsewhere are also included.

The abstracts are grouped into five sessions:
(1) Water Operations in the Face of Extreme Events,
(2) Monitoring Water Availability,
(3) Sustainability and Climate,
(4) Factors Affecting and Affected by Droughts, and
(5) Coastal Water Systems.

The detailed agenda and presentations can be found at http://www.jsg.utexas.edu/ciess/drought-symposium/.

Organizing Committee:
Zong-Liang Yang[1], David Maidment[1], Jessica Smith[1], and Brenner Brown[2]

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Real-Time Water Operations Model

David Maidment[1], Kathy Alexander[2,*], Fernando Salas[1,*] and Tim Whiteaker[1, *]
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The Texas Commission on Environmental Quality has the role of permitting surface water diversions from Texas rivers and reservoirs, and the responsibility of managing these diversions when insufficient water is available to support all those who desire to divert water. To better support this decision-making, a real-time water operations model has been established for the San Antonio and Guadalupe River basins that combines water observations from the US Geological Survey, forecasts from the National Weather Service, diversion information from the TCEQ, and modeling of the flow in each of 5500 river reaches in these basins. This presentation will describe the motivation for establishing this model and its basic architecture.

*Presenting author

Real-Time Water Modeling and Decision Support Framework

Barbara Minsker[1,*], Erhu Du[1], Jong Lee[1], Tingting Zhao[1], David Maidment[2], Fernando Salas[2] and Zong-Liang Yang[2]

[1]*University of Illinois Urbana–Champaign;* [2]*University of Texas at Austin*

Protecting food and energy supplies, as well as numerous other industries, requires rapid and informed decision making during water crises, particularly floods and droughts. While the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) provides flood and drought warnings across the nation, such operational systems currently have limitations in forecasting with the accuracy and real-time awareness needed to support effective disaster planning and response. This project is demonstrating the value of regional real-time river modeling services that perform fine-scale modeling and decision support in drought- or flood-stricken areas. Real-time National Weather Service (NWS) simulations and forecasts are being used to support RAPID, a large-scale river flow model developed at the University of Texas Austin, which then feeds into decision support services developed at University of Illinois. A Web-based model visualization and scenario builder application has been created, available at http://rapid.ncsa.illinois.edu:8080/rapid2. This will be linked with real-time optimization algorithms and water market tools to support decision makers during droughts. Real-time data and modeling services, as well as confidence intervals to provide uncertainty estimates, will be distributed through online data markets to enable widespread use of the services developed in this project.

*Presenting author

Real-Time Water Decision Support Services for Droughts

Tingting Zhao[1,*], Barbara Minsker[1], Jong Lee[1], Fernando Salas[2], David Maidment[2] and Cedric David[3]

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Through application of computational methods and an integrated information system, real-time data and river modeling systems can help decision makers identify more effective actions for management practice. The purpose of this study is to develop a real-time decision support model to recommend optimal curtailments during water shortages for decision makers. To enable ease of use and re-use, the workflows (i.e., analysis and model steps) of the real-time decision support model are published as Web services delivered through an internet browser, including model inputs, a published workflow service, and visualized outputs. The model consists of two major components: the real-time river flow prediction system and the optimization model. The RAPID model, which is a river routing model developed at University of Texas Austin for parallel computation of river discharge, is applied to predict real-time river flow rates. The workflow of the RAPID model has been built and published as a Web application that allows non-technical users to remotely execute the model and visualize results as a service through a simple Web interface. An optimization model is being developed to provide real-time water withdrawal decision support using the RAPID output and the clustering particle swarm optimization algorithm (CPSO) and genetic algorithm methods. The model is being tested using historical drought data from 2011 in the Upper Guadalupe River Basin in Texas. The objective of the optimization is to assist the Texas Commission on Environmental Quality (TCEQ) in minimizing the total daily curtailment hours of all permit holders, with constraints on user seniority and ecological river flow. The optimization model workflows is linked to the RAPID model workflow to provide real-time water decision support services. Finally, visualization of the output using Bing-map and WorldWide Telescope helps decision makers predict outcomes from alternative weather or policy scenarios.

*Presenting author

Simulating the Feasibility and Performance of a Real-Time Water Market in Guadalupe River Basin, Texas, by Coupling an Agent-Based Model and RAPID Model

Erhu Du[1], Barbara Minsker[1] and Ximing Cai[1]

[1]*University of Illinois Urbana–Champaign*

Under the conditions of both global and local water shortage and fully committed water diversion rights, market-based water allocation (such as a water eBay) could be a promising instrument for water saving and redistribution from marginally profitable areas to highly profitable ones, allowing junior water right holders to obtain water from senior water right holders. However, both the institutional issues (e.g., transaction costs, water transfer challenges, etc.) and environmental factors (e.g., climate uncertainty, impacts on downstream river flows, river network distribution, etc.) complicate implementation of a water market system.

We have proposed an agent-based modeling approach to predict the adaptive water usage behaviors of heterogeneous water right holders under a real-time water market system. (Each water user is defined as an "agent" that makes water diversion decisions based upon adaptive water usage rules under different water availability scenarios.) RAPID model, which is a hydrologic model that predicts river flow in river networks, will be coupled with the agent-based model to simulate the hydrologic impacts of a real-time water market under different water availability scenarios.

Our preliminary results from this framework evaluate agricultural resilience to climate uncertainty under a real-time water market system in an agriculture district in Guadalupe River Basin, Texas. The agricultural resilience is measured by coefficient of variance of the crop yield under different drought scenarios. The results indicate that a real-time water market is capable of increasing crop yield (corn) by 10.56% in dry scenarios and 2.01% in wet scenarios. The resilience could be increased from 0.57 to 0.64 in dry scenarios and from 0.75 to 0.78 in wet scenarios. Water usage efficiency could be increased from 9.34 bushel/inch to 9.52 bushel/inch in wet scenarios, and from 14.82 bushel/inch to 15.57 bushel/inch in dry scenarios.

In future work, we will compare a real-time water market's impacts under different water rights auction mechanisms. The spatial distribution of water users and transaction costs of water rights trading will also be considered with the coupled agent-based and RAPID model.

*Presenting author

Drought in Texas: How the State Prepares for and Responds to Drought

Brenner Brown[1,*]
[1]*Texas Water Development Board, Austin, TX*

I would like to address:

- Regional Planning Process
- State Water Plan
- Water Management Plans
- Drought Contingency Planning
- Drought Preparedness Plan
- Annex A of Emergency Drinking Water

I will also include some anecdotal information from the Drought of Record.

*Presenting author

Applying Coupled Noah-MP and RAPID in Reservoir Level Simulation:

A Case Study in Lake Buchanan, Texas

Peirong Lin[1, *], Zong-Liang Yang[1], Cédric H. David[2], Ron Anderson[3] and Xitian Cai[1,]
[1]*University of Texas at Austin;* [2]*University of California Center for Hydrologic Modeling, Irvine, CA;* [3]*Lower Colorado River Authority, Austin, TX*

Numerical climate models are increasingly being used by climate scientists to inform water management. In this study, we investigate the applicability of a new modeling framework using the Noah land surface model with multi-parameterization options (Noah-MP) along with the Routing Application of Parallel computatIon of Discharge (RAPID) in simulating reservoir level changes using a mass balance approach. RAPID is a deterministic large scale river routing model which allows for realistic "blue lines" from GIS datasets as its river network while remaining compatible with grid-based LSMs.

Here, a case study is conducted over a medium-sized reservoir (~80,000 acre-feet capacity), which is locally called Lake Buchanan, from 2000 to 2007 using a monthly time step. We take a subset of RAPID run on Noah-MP LSM 4.5-km runoff (surface and subsurface), and connect the 14 inflows with Lake Buchanan described by NHDPlus2 water body dataset. Precipitation and lake evaporation are estimated from Noah-MP 12.5-km data. Outflows are calculated by summing turbine release, gate release and diversions from Buchanan dam documentation. Initial results show that the modeling framework based on best available knowledge on land surface processes and river routing can reasonably reproduce Lake Buchanan historical level changes despite cumulated errors. Some tributary contributions during flooding cases, which are ignored by operational models, can also be captured in this model. The uncertainties of different components of the mass balance model are also analyzed.

This modeling framework potentially opens the possibility of applying operational atmospheric forecasts in short-term and long-term hydrologic forecasting at regional scales.

*Presenting author

GIS-Based Modeling Approach to Estimate Nitrogen Loading and Load Reduction in Lakes/Reservoirs with Application to the San Antonio and Guadalupe Basins

Ahmad A. Tavakoly[1,*], David R Maidment[1], Zong-Liang Yang[1], Tim Whiteaker[1], Lisa H. Meyer[1] and Cedric H. David[2]
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The effect of climate change, land use on nutrient transport, and the movement of nutrients from the atmosphere to landscapes and consequently to the coastal areas are very sophisticated and tightly linked process. The consequences of overabundant nutrients on riverine export emphasize the necessity to improve our understanding of nitrogen transport in large costal watersheds. Various water quality models from complex deterministic to simple export coefficient approaches have been developed to evaluate nitrogen loads in river basins. Deterministic models describe in detail the nitrogen transport, attenuation, and transformation. As a result, they allow to better understanding of spatial and temporal variations in sources and sinks included in watersheds. Insufficiency of water quality data and weakness of uncertainty measurement prevents the implementation of complex deterministic models.

This study explains a development of GIS framework to integrate a GIS-based nitrogen dataset (Texas Anthropogenic Nitrogen Dataset) and river routing model to simulate steady-state riverine nitrogen transport and chemical reactions in river networks. We are conducting a 2-year case study (2008-09) along all rivers in the San Antonio and Guadalupe basins and investigating total nitrogen change in urban and rural regions (San Antonio and Guadalupe) during wet and dry years.

*Presenting author

Publishing and Federating Global Water Data and Maps via Web Services

David Arctur[1,*]

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Finding and accessing data in most countries of the world about local, regional and national water resources (streamflow discharge, gauge depth, soil moisture, etc.) has been complicated by a number of issues, from concerns of local and national security, to lack of suitable conventions and standards for data exchange that could be reasonably implemented and enforced at the national and international levels. These issues are now starting to be addressed, thanks to recently adopted standards for hydrologic data exchange, and growing acceptance of community standards for web services to perform such data exchange. This presentation reviews recent work in this area, in particular from an international initiative to federate regional water data into national pictures for Italy, New Zealand, Canada, and a growing number of countries in Latin America. This builds on previous similar work by the Consortium of Universities for Advancement of Hydrologic Science (CUAHSI) with the U.S. Geological Survey and several other U.S. national agencies. The ability to discover and access such important data should improve the awareness and responsiveness of policy- and decision-makers in the event of natural disasters from storms, flooding and drought.

*Presenting author

Land Cover Effects on Watershed Hydrologic Memory

Jason P. Julian[1,*] and Robert H. Gardner[2]
[1]*Texas State University;* [2]*University of Maryland Center for Environmental Science*

The response of a river's flow regime to climatic events such as drought is influenced by the watershed's hydrologic memory. This presentation demonstrates how the technique of power spectral analysis can be used to determine the hydrologic memory of watersheds across multiple spatio-temporal scales. We then compare the hydrologic memory of 87 watersheds (first to seventh order) within the eastern Piedmont (USA) to land cover and other physiographic variables to assess the effects of land cover on hydrologic memory. The effect of land cover on hydrologic memory was confirmed. Urban-dominated watersheds were flashier and had less hydrologic memory compared with forest-dominated watersheds, whereas watersheds with high wetland coverage had greater hydrologic memory. We also detected a 10–15% urban threshold above which urban coverage became the dominant control on flow regimes. When spectral properties of river discharge were compared across stream orders, a threshold after the third order was detected at which watershed processes became dominant over precipitation regime in determining flow regimes. Finally, we present a matrix that characterizes the hydrologic signatures of rivers based on precipitation versus landscape effects and low-frequency versus high-frequency events. The concepts and methods presented can be generally applied to all river systems to characterize multi-scale flow regimes and potential drought responses.

*Presenting author

Soil Moisture and Drought in Texas

Todd G. Caldwell[1,*], Bridget R. Scanlon[1], Michael H. Young[1] and Di Long[1]
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For this presentation, we will relate the drought of 2011 to our knowledge of soil moisture from modeling and monitoring data in Texas, and we will present ideas for how to operationalize soil moisture information to improve decision making. *Drought is inevitable in Texas. Drought is defined many ways; nonetheless soil moisture is intimately linked to it.* While meteorological drought, a departure from normal precipitation, affects near-surface soil moisture storage and agricultural drought related to crop and rangeland production, hydrological drought impacts our water resources. An inherent time lag exists between the two and soil moisture is the connecting link. Unfortunately, our infrastructure for measuring soil moisture storage in Texas is not adequate. For example, the drought of 2011 led to total water storage deficits in excess of 80 million acre-feet, and our best numerical models indicate that 20-80% of this deficit came from soil moisture storage, the rest coming from reservoir storage and groundwater. We will explain the reasons behind the large range in deficit attributed to soil moisture, why our current monitoring capabilities are not sufficient to reduce this range, and why this matters to decision makers. We will suggest approaches that can be taken to mitigate this large knowledge gap and show that linking soil moisture at a higher level can improve our drought contingency planning, water resource forecasting, and more clearly illuminate drought impact and duration. Single-year meteorological drought results in multi-year hydrological impact and soil moisture status can provide invaluable information to water planning decisions.

*Presenting author

Hydrology from Space: NASA's Satellites Supporting Water Resources Applications

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NASA's Earth Science Mission Directorate Applied Sciences Program is supporting a formal effort to optimize the value of upcoming NASA Earth missions to a broad user community and to society at large. The objective of these mission applications programs is to pave the way for expanded operational use of NASA's future Decadal Survey missions, which includes GRACE-FO, SWOT, SMAP, GPM, NISAR and other planned hydrology-relevant missions. We will also provide an overview of current NASA missions that provide hydrologically relevant measurements, such as on TRMM and AIRS.

The goals of the NASA mission applications programs include:

- Promoting the use of mission data products to a community of end-users and decision makers that understand the mission capabilities and are interested in using the relevant data products in their application
- Facilitating feedback between the user communities and the NASA projects
- Providing a link to the scientific information from complex space mission data that are relevant to managing coastal environments, regions having great potential of droughts and floods, and the nuanced impacts that changes in both the near surface water and deep aquifer environment have on agriculture and other human activities.
- Designing communication strategies to target and support requirements of the user community.

A number of NASA missions currently provide global measurements of the Earth's hydrological cycle. The future missions will carry on these important measurements, and will provide new data on soil moisture, surface water extent, state of the deep aquifers, atmospheric water transport, and other important parameters. They will continue to provide information on seasonal and inter-annual river basin water storage changes, human influences on regional water storage changes, large-scale evapotranspiration, land-ocean mass exchange, and continental aquifer changes.

Planned strategies to enhance science and practical applications of GRACE data will be discussed, including methods of engaging with the science community, operational users, and mission planners.

*Presenting author

GRACE Satellite Monitoring of Large Depletion in Water Storage in Response to the 2011 Drought in Texas

Di Long[1,*], Bridget R. Scanlon[1], Laurent Longuevergne[2], Alexander Y. Sun[1], D. Nelun Fernando[3,4] and Himanshu Save[5]
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Texas experienced the most extreme one-year drought on record in 2011 with precipitation at 40% of long-term mean and agricultural losses of ~$7.6 billion. We assess the value of Gravity Recovery and Climate Experiment (GRACE) satellite-derived total water storage (TWS) change as an alternative remote sensing-based drought indicator, independent of traditional drought indicators based on in situ monitoring. GRACE shows depletion in TWS of 62.3 ± 17.7 km3 during the 2011 drought. Large uncertainties in simulated soil moisture storage depletion (14–83 km3) from six land surface models indicate that GRACE TWS is a more reliable drought indicator than disaggregated soil moisture or groundwater storage. Groundwater use and groundwater level data indicate that depletion is dominated by changes in soil moisture storage, consistent with high correlation between GRACE TWS and the Palmer Drought Severity Index. GRACE provides a valuable tool for monitoring statewide water storage depletion, linking meteorological and hydrological droughts.

*Presenting author

Fire, Earth, and Water: Soil Moisture Dynamics across a Wildfire Burn Boundary Resulting from the 2011 Labor Day Bastrop County Complex Fire

Michael R. Kanarek[1] and M. Bayani Cardenas[1,*]
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A year after the most destructive wildfire in Texas history which occurred in and around Bastrop State Park, we established a 165 m-long study transect, bridging burned and unburned areas, to study post-wildfire soil moisture dynamics. Soil moisture content was measured approximately monthly for half a year using a variety of methods including: 2D electrical resistivity (ER) imaging and surface and vertical profiles using probes which measure soil dielectric properties. The burned section, where the majority of loblolly pine trees were killed, had higher moisture content and lower ER whereas the unburned end which is still populated by live trees had lower moisture content and higher ER. This pattern persisted from the ground surface and down to ~ 2 m and through the study period even after a rainfall event which made the whole transect generally wetter but with the burned end showing a much stronger wetting response to the storm. The differences in moisture content cannot be explained by differences in soil texture with the burned end with sand soil and the unburned end with less permeable loamy sand. The results suggest that the differences are due to loss of canopy cover and reduced transpiration at the burned end where the dead roots may also potentially serve as macropores. Thus, after fires and until new vegetation cover has grown, the burned areas will store and transmit more water which could lead to increased recharge in aquifers and promote the recovery or invasion of certain types of vegetation.

*Presenting author

Drought and the Water Energy Nexus in Texas

Bridget R. Scanlon[1,*], Ian Duncan[1] and Robert C. Reedy[1]
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Increasing extent, frequency, and intensity of droughts raises concerns about the vulnerability of electricity generation to water-shortages. Here we evaluate the record breaking 2011 drought in Texas as a microcosm of drought-related water shortage impacts on electricity generation. We quantified water use for each power plant during drought (2011) and nondrought (2010) periods and compared water use to water supplies to assess drought vulnerability and examine adaptation strategies. Although counterintuitive, drought impacts were greater in sub-humid east Texas than in semiarid west Texas (where plants are mostly pre-adapted to low water availability), a proxy for climatic differences between eastern and western US. High temperatures with ≤100 days of triple digit temperatures raised electricity demands/generation by 6% relative to 2010 and water demands/consumption for increased thermoelectric generation by ~10%. In contrast, water supply decreased markedly with statewide reservoir storage at record lows (58% of capacity). Reductions in reservoir storage would suggest drought vulnerability but data show that power plants subjected to extreme water shortages, as occurred in 2011, were flexible enough at the plant level to adapt by switching to less water-intensive technologies, such as from once-through cooling to cooling towers and from steam turbines to combustion turbines (no cooling water requirements). Increasing natural gas production and use in combined cycle plants by an order of magnitude greatly enhances resilience of the power-plant fleet to drought by reducing water consumption (~1/3rd of that for steam turbines), and allowing plants to operate as base-load or peaking plants to complement increasing wind generation. Drought proofing the system can be further enhanced by reducing demand and/or increasing supplies of water (e.g. municipal waste water or brackish water) and electricity. Joint management of water and electricity would greatly improve our ability to cope with projected increases in droughts.

*Presenting author

Hydraulic Fracturing Water Use in the Eagle Ford Shale Play: A Systems Dynamics Approach

Jeanne Eckhart[1,*]
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The process of extracting oil and gas through hydraulic fracturing utilizes a significant amount of water per an event. The Eagle Ford shale play uses between about 1 million gallons to about 13 million gallons per a hydraulic fracturing event which can cause significant impacts for that region. Relatively speaking hydraulic fracturing is a small portion of the water usage in the state of Texas, but it is important to consider how large of a portion it is for a regional or more localized area. This research examined water usage in counties, hydraulic fracturing events, and the impacts of the drought to the area. The uneven distribution of water has led to drought stricken regions within Texas that are impacted from the oil and gas industry that are using large amounts of water within their county. This research examines the sources of water that oil and gas companies use in the area, and other impacts that water usage may have. A significant portion of water utilized in this region is from groundwater, and is vital to understand the effects that this may have on other industries, like agriculture. The holistic systems dynamics approach of this research allows for collaboration with the many different stakeholders in the region to understand the water usage needs more, as well as to understand how the energy companies, local regulating entities, and others involved interact. The need to recognize the impacts that hydraulic fracturing has on water sources in a regional manner are important for the general public and policy makers, therefore a comprehension of technological improvements in hydraulic fracturing and the management of an oil or gas well site is required. This case study assessed that the Eagle Ford shale play area should reassess the water usage from the oil and gas operations in the coming future to get a more accurate and robust data set that can provide more information about impacts.

*Presenting author

Socio-Economic Impacts of Agricultural Drought on the Texas Economy

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In 2011, almost 90% of the areas in Texas were classified in exceptional drought conditions (NDMC, 2013). As a result, many sectors in the Texas economy have suffered tremendous economic losses, especially agriculture. With almost 12 million head of livestock and 130 million acres of crop land, Texas ranks number one among the US states in the value of livestock, poultry, and their products, and number three in terms of the total value of agricultural products sold in the country (USDA, 2011).

The 2011 drought in Texas caused an estimated $7.6 billion loss in the agricultural sector, with livestock, cotton, and grain production being the most affected (Fannin, 2012; Guerrero, 2012)
This paper analyzes economic implications of the 2011 Texas agricultural drought on the state economy. By using an input-output and social accounting matrix model, direct effects have been estimated on animal, cotton, sorghum, wheat, corn, hay and timber production, as well as indirect effects on other related sectors. In addition, induced effects for consumers have also been estimated.

The results of the analysis indicate that the 2011 drought caused economic losses of $16.9 billion in the entire Texas economy and increased the unemployment by 166,895. The agricultural sector alone lost 106,000 jobs. Cotton farming lost 91% of its production value (compared to the 2010 base year) while the animal sector lost $3.7 billion in production (32% compared to 2010). The decreased production yields and the limited market supply directly influence market prices for those products, which creates additional effects on export quantities and domestic consumption prices.

The analysis may be helpful in designing policies to mitigate impacts of future droughts.

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*Presenting author

It Takes a Village: Facilitating Public Input on Drought Management and Conservation Policy

D. Gross[1,*]
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This paper will examine the methods used in Austin, Texas in 2012 to facilitate public input on drought policy in a politically-sensitive environment and during an exceptional drought.
In late 2011, Central Texas was in an exceptional drought, and for the first time the City of Austin faced the possibility of enacting Stage 3 water use restrictions, which essentially prohibited outdoor water use. In response to concerns from businesses and residents about the impact of such restrictions on landscapes and tree canopy, Austin launched a public input process to revise the City's water use management code and drought contingency plan.

This paper will outline how Austin Water staff worked to educate customers about conservation and drought management, regional water supply and business concerns. Attendees will learn the different approaches used at both small and large group meetings, what tactics and exercises seemed to work for each setting, and what surprising measures found public support. The paper will provide ideas for utilities who are considering implementing or revising long-term conservation and drought plans to ensure support from the public and government officials.

*Presenting author

Coordinating Texas Water Research

Jay Banner[1,*] and Eric Hersh[1]
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Water of sufficient quantity and quality for Texas and for Texans is of the utmost importance. Beyond the infrastructure costs outlined in the State Water Plan, there is also a need to gather the best data and to develop the best science to determine: (1) the processes, such as drought, that affect the distribution of water in the state today and tomorrow, (2) the technologies for increasing supply or decreasing demand; and (3) the impact of Texas' population, economic, and energy sector growth.

Solutions to Texas' water challenges may be found in part within the halls of our state's universities, where researchers and students are continually advancing water resources science, technology, and policy. For such a complex and multi-faceted problem as Texas' water future, a coordinated integration of this research is essential, yet lacking, across departments, campuses, and systems. These universities represent a source of considerable pride for Texans, and they also represent a considerable investment of state and taxpayer resources. With research coordination in the area of water resources, Texas could maximize the productivity of its investment in its state universities and could realize potential synergies between researchers and between research institutions. This need for research coordination also includes experts at governmental agencies, in industry, in private not-for-profit entities, and stakeholders.

There are a number of ways that such a state-wide coordination effort might work. For example, a diverse statewide panel of experts and stakeholders could be convened periodically to identify the current water and climate challenges facing our state and to provide the best science, technology, and socio-economic information on Texas' water future. We outline the need for coordinating Texas water research and potential avenues for progress toward that goal.

*Presenting author

Explore a Process-Based Early Warning Indicator for "Flash" Droughts over the US Great Plains in Supporting US Drought Monitoring and Prediction

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"Flash" droughts refer to those droughts that intensify rapidly in spring and summer, coupled with strong increase of summer extreme temperatures, such as those that occurred over Texas in 2011 and the Great Plains in 2012. Climate models failed to predict these "flash" droughts in 2011 and 2012 and are ambiguous in projecting their future changes, in part because of their relatively large uncertainty in representing summer convection and land surface feedbacks. By comparison, climate models are more reliable in simulating changes of large-scale circulation and temperatures during winter and spring seasons. To mitigate the weakness of the current climate models and take advantage of the models strength, we have developed a prototype early warning indicator for the risk of summer "flash" droughts by using the anomalous climate conditions in winter and spring. This indicator is constructed in a way similar to drought severity indices shown at National Integrated Drought Information Center (NIDIS). We will present the preliminary results and discuss the underlying physical processes related to this indicator.

*Presenting author

Spatial Variability of Summer Precipitation Related to the Dynamics of the Great Plains Low-Level Jet

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Diurnal variations of the Great Plains low-level jet (GPLLJ) and vertical winds have been related to the development of summer precipitation individually, but their underlying connection and consequences for the nocturnal and afternoon precipitation peaks less discussed. This work examines how together they are related to the spatial pattern of the frequency of summer convective precipitation over the Great Plains. A one-layer linearized boundary layer model is used to reproduce the diurnal cycles of the GPLLJ. Its periodic rising and sinking motions are compared with those of the North American Regional Reanalysis (NARR) climatology.
Its development of rising motion is consistent with the enhanced occurrence of nocturnal convective precipitation over the central and eastern Great Plains (90º-100ºW) and afternoon maximum over the western Great Plains (100º-105ºW), while precipitation occurs in these regions of opposite phase half a day later. The phase shift of the vertical winds can be captured by the model only if the diurnal oscillation of the jet is well represented, i.e., when both near surface geopotential gradients and friction are used to drive the model.

The diurnal variation of the vertical winds (or boundary layer convergence/divergence) is explained by local vorticity balance, i.e., the diurnal oscillation of the jet changes the zonal gradient of the meridional wind and thus relative vorticity. The intensification of the jet during the night leads to anomalous cyclonic vorticity to the west of the jet core and anticyclonic vorticity to the east; the pattern reverses during daytime when the jet is relatively weak. Anomalous rising (sinking) motions occur to balance these positive (negative) vorticity tendencies.

The variation of the low-level vorticity is also closely related to the GPLLJ on the interannual time scale. The first two EOFs of low-level vorticity are significantly correlated to the meridional winds over the jet core and exit area and correspond to precipitation variations over the mid-West and eastern U.S. Vorticity variations in the southern Great Plains are also significantly correlated with local precipitation variations and weakly related to meridional winds over the south coast.

*Presenting author

Understanding Spring Soil Moisture–Precipitation Feedback in the SGP: the Role of Large-Scale Atmospheric Conditions

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The spring precipitation in the Southern Great Plains (SGP) has exhibited strong inter-annual variability. Among other mechanisms, the locally derived land-atmosphere interaction has been shown to play an important role in reshaping precipitation anomaly. However, the mechanistic understanding about the magnitude and sign of the feedback remains inadequate. The uncertainties stem in part from how and to what extent ET anomaly controls precipitation, a key component of S–P interaction. The current study seeks to unravel the potential role played by large-scale atmospheric conditions in shaping S (ET)–P feedback. Our research demonstrated the characteristic atmospheric flow patterns associated with different S–P feedback composites, and their impacts are understood from perspective of large-scale disturbance, e.g., the frequency and strength of storm track. Further, the connections between low-level moisture condition and S–P feedback patterns are evaluated. Probing these problems contributes to a comprehensive understanding of regional S–P coupling in terms of its reliance on season, geographical location, and related hydro-meteorological variables and processes.

*Presenting author

Annual Variability in Leaf Area Index and Isoprene/Monoterpene Emissions in Texas during Drought Years

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Vegetation has an important influence on tropospheric chemistry and global climate forcing and serves as a sink for atmospheric pollutants through dry deposition. Isoprene and monoterpenes are quantitatively among the most important biogenic volatile organic compounds (BVOCs) emitted globally from vegetation. The role of BVOCs in the formation of tropospheric ozone in Texas has been recognized as critical for air quality planning. A pathway through which drought may affect predictions of BVOC emissions and ground-level ozone formation is through changes in leaf area index (LAI), a key model input parameter representing the ratio of total upper leaf surface of vegetation to land surface area. Spatial and annual variations in the 4-day LAI product derived from the Moderate Resolution Imaging Spectroradiometer (MODIS) on-board the Terra and Aqua satellites and the relative effects of LAI versus other input parameters on predictions of biogenic emissions in Texas using the Model of Emissions of Gases and Aerosols from Nature (MEGAN) were examined for four climate regions in eastern Texas during 2006 through 2011. LAI exhibited a strong seasonal pattern and varied between climate regions even for the same land cover types. Maximum monthly inter-annual variability in LAI exceeded 20% for land cover types in North and South Central Texas, but less than 20% in East Texas and the Upper Coast during the six-year period. Deviations in predicted isoprene and monoterpene emissions were well-correlated with deviations of LAI. In North and South Central Texas, isoprene and monoterpene emissions were notably lower (by as much as -22%) due to significant reductions of LAI during the onset and persistence of drought in 2006 and 2011. Annual changes in meteorological fields for temperature, wind speed, photosynthetically active radiation (PAR), and humidity collectively contributed to larger inter-annual variability in isoprene and monoterpene emissions than LAI alone. LAI and meteorological factors may have complex and perhaps competing impacts on isoprene emissions.

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The Role of the Mexican Plateau in Shaping Rainfall over Texas

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Analyses of satellite observations and reanalysis data show the impact of the Mexican Plateau (MP) on rainfall over Texas in spring and summer. The Community Earth System Model was used in this study to examine the role of the MP on the hydro-climate over the southern US, providing implications for the linkage between the MP and rainfall over Texas. A control run and three experimental runs were performed with prescribed sea surface temperatures and sea ice fractions. The results show that when the MP becomes dry, rainfall declines locally and downstream. During the spring, the dry air brought to Texas by prevailing westerly winds suppresses local convection; but dry air advection from the highlands has little influence on rainfall over Texas during the summer when Texas is no longer in the downstream areas. During the summer, a warmer MP acts like a “moisture pump” that pushes moist air over the peripheral low elevation areas to the highlands; it bends the low-level jet towards the highlands and an anti-cyclonic flow anomaly forms over the southern US, which tends to diverge the air and reduce rainfall over the southern US.

*Presenting author

Inclusion of a Simple Reservoir Model in Regional-Scale Surface Water Modeling

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The modeling of the horizontal movement of water from land to coasts at scales ranging from 10^5 km^2 to 10^6 km^2 has benefited from extensive research within the past two decades. In parallel, community technology for gathering/sharing surface water observations and datasets for describing the geography of terrestrial water bodies have recently had groundbreaking advancements. Yet, modeling and observations have barely started to work hand-in-hand, and much research remains to be performed before we can better understand the anthropogenic impact on surface water through combined observations and models. In particular, despite their importance for water supply particularly in drought conditions, man-made reservoirs are often overseen in current hydrologic modeling approaches. Here, we build on our existing river modeling approach that leverages community state-of-the-art tools such as atmospheric data from the second phase of the North American Land Data Assimilation System (NLDAS2), river networks from the enhanced National Hydrography Dataset (NHDPlus), and observations from the U.S. Geological Survey National Water Information System (NWIS) and from the California Data Exchange Center (CDEC). Modifications are made to our integrated observational/modeling system to include a simple treatment to characterize man-made reservoirs. Initial results of a study focusing on the entire State of California suggest that such implementation allows improving river flow simulations while providing a valuable estimate for water storage in large reservoirs.
http://www.ucchm.org/david/rapid.htm

*Presenting author

Understanding Hawaiian Sustainability via Maui Water Availability, Changing Rainfall Trends, and Island Sustainability

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"*The rain follows the forest*. From Hawaii's forest come streams that collect much of this rain, and the water in these streams enables much of the cultural, ecological, and economic value on the islands. Hawaii's future sustainability is linked to its use of water resources. The Island of Maui is certainly no different. In many ways, Maui exemplifies the need for Hawaiians to consider how they will adapt to climatic and economic changes that originate both from within and from without the Hawaiian Islands.

The analysis described in this presentation focuses on the water and energy inputs and outputs for producing both biofuel feedstocks in the Central Plain of Maui and food crops in the Maui Upcountry. The system water, food, and energy scenarios in this presentation are based upon the idea that Maui's water supplies are becoming increasingly constrained due to changes in climate, increasing native and visitor populations, and movements and legal rulings to reduce water diversions from streams for both environmental and native cultural reasons (e.g. taro farming).
Overall, there is a significant opportunity to meet multiple sustainability goals using the same or a lesser quantity of water for large-scale farming of biofuel crops in central Maui. These multiple goals include more local food, increased renewable energy, and living in a sustainable manner, particularly with regard to groundwater usage."

*Presenting author

Methodology for Applying GIS to Evaluate Hydrodynamic Model Performance in Predicting Inundation

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Accurate inundation predictions are critical to habitat conservation, littoral boundary definition and coastal planning. Validating a predictive hydrodynamic model against ground observations is essential to the evaluation of model performance. The output of a typical hydrodynamic model provides georeferenced predictions that can be used to delineate a wet/dry boundary. This paper presents two geospatial methods that were developed utilizing the Coastal Modeling System (CMS) hydrodynamic model and ArcMap software. In general, the techniques should be applicable to other calibrated and georeferenced models. The methods may be applied independently or in conjunction. Each method was validated with an extensive dataset available for tidal flats located along Packery Channel, Texas. Method #1 compared model predictions to the observed conditions of high resolution aerial and satellite imagery which are classified using one of two geospatial processes. Method #2 applies the model output to delineate the maximum flood extent of 5 test cases (including 3 cold front events) and then compares the predicted extent to topographic surveys which define the true time-dependent flood line. Method #1 was applied to 11 test cases for which reliable high-resolution aerial and satellite imagery were available while Method #2 was based on 5 topographic surveys. The hydrodynamic model was well calibrated with average absolute errors ranging from .026 to .125 m/s for current predictions. Analysis which quantified agreement between model predictions and classified imagery ranged from 69% to 91%. This methodology expands present capabilities to assess and improve hydrodynamic model predictions, particularly for inundation delineation in shallow coastal environments and coastal settings strongly influenced by non-tidal factors such as wind.

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