Vol. 18 • No. 1

Department of Civil & Environmental Engineering

CEE IN FOCUS

FALL **2018** • VOLUME **18** • Number **1**

FROM THE DEPARTMENT CHAIR

A letter from George Z. Voyiadjis

I welcome you this fall with many events occurring in our department, the university, and the state. Two new faculty members joined our department this fall—Geotechnical Assistant Professor Dr. Hai "Thomas" Lin and Geodesy Research Assistant Professor Dr. Ahmed Abdalla. We welcome both of them to our department.

The October 2018 issue of *Civil Engineering* magazine featured an article written by Robert L. Reid titled *"Big River, Big Model"* that discussed LSU's state-of-the-art river model. The model, which is housed in the LSU Center for River Studies, is a scaled-down version of the Mississippi River with images generated on it to show what will happen to areas along the river in the future.

In this newsletter, we highlight several projects that LSU faculty and students are engaged in. Some of these projects include wind engineering, connected/autonomous vehicles (CAVs), research experience in geoid modeling and its applications, and monitoring of bridges in Louisiana. We also feature a $3.1 million grant for the Center of GeoInformatics (C4G) that was awarded by the National Oceanic and Atmospheric Administration (NOAA) to support and enhance regional geospatial modeling for coastal Louisiana.

The annual ASCE at LSU Career Fair held on October 18 was a great success and had the highest student attendance of any fair yet. This event also had the most organizations of any ASCE Career Fair to date, all of which were recruiting civil engineers. Building connections and hearing from professionals in the engineering fields are extremely beneficial for young prospective engineers, and the ASCE Career Fair is the best way for civil engineering students and employers to connect.

Sincerely,

Dr. George Z. Voyiadjis, Boyd Professor, Chair and Bingham C. Stewart Distinguished Professor

DEPARTMENT HIGHLIGHTS

THE WINDSTORM IMPACT, SCIENCE, AND ENGINEERING FACILITY (WISE)

Due to significant climate change, stringent windstorms are becoming more frequent than ever. Given the threat that windstorms bring to people and property, wind/structural engineering research is imperative to improve the resilience of existing and new infrastructure for community safety and assets protection. CEE Assistant Professor Dr. Aly-Mousaad Aly has been instrumental in developing the Windstorm Impact, Science, and Engineering (WISE) research program at LSU. WISE focuses on creating new knowledge applicable to the mitigation of existing and new infrastructure, to survive and perform optimally under natural hazards (Figure 1).

Characterization of Realistic Wind Forces on Buildings and Other Types of Structures: To address this challenge, the LSU WISE research program combines the benefits of state-of-the-art experimental/computational facilities to accurately reproduce the physics as well as aerodynamic phenomena inherent in atmospheric boundary layer (ABL) flows around buildings and other bluff bodies. The LSU WISE research group has access to experimental and computational facilities that include small and large-scale open-jet hurricane testing capabilities, a boundary layer wind tunnel facility with high and low-speed test sections, and high performance computing (HPC) resources for computational fluid dynamics (CFD) simulations with OpenFOAM for the simulation of ABL flow turbulence, employing advanced closures, such as the Reynolds Stress Model (RSM) and Large Eddy Simulations (LES) with realistic inflow fluctuations. This research mainly focuses on developing a hybrid mathematical informatical holistic approach to dealing with scale issues in the simulation of wind flows around buildings, to ascertain correct evaluation of peak loads with a potential to enhance and update design standards.

Open-Jet Testing: For several decades, wind tunnels were employed to estimate wind forces on structures. The experimental characterization of wind loads on buildings and other types of structures requires scaling of the test object and flow, under the constraints of relevant dimensionless parameters (laws of similitude), to ensure the physics in the laboratory are representative of those at full-scale. Reynolds number and turbulence structure are two influential parameters that have been either underestimated or their exact role was neglected for decays. Wind loads on certain bluff bodies, like those with cylindrical shapes and rounded edges, may be significantly affected by the Reynolds number. However, the common belief that Reynolds number effects on sharp-edged structures are negligible is questionable these days for two reasons: (1) recent full-scale structural failure and the mismatch in data obtained from full-scale measurements and laboratory testing, and (2) the new capabilities of testing at higher Reynolds numbers such as those of open-jet facilities. In addition, evidence that the Reynolds number affects aerodynamics of bodies with sharp edges was obtained from tests in pressurized wind tunnels.

Figure 1: *Long-term research goals of the LSU WISE research program*

In testing high-rise buildings, the ratio of the integral length scale of turbulence to the structural geometric scale in wind tunnel testing may be similar to full-scale. In testing of low-rise buildings and small-size structures, however, producing turbulence in the laboratory at reasonably large integral scales is a challenge. Testing low-rise buildings at smaller geometric scales is also a challenge because of the uncertainty in the

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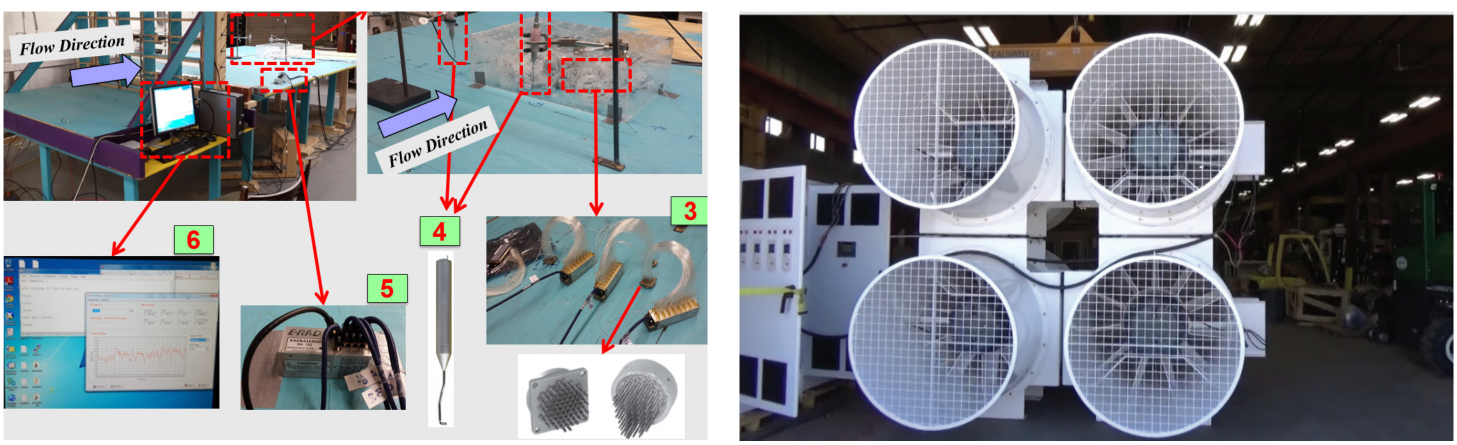
flow velocity near the ground, and the difficulty to obtain high resolution pressure data. Also add in the effects of interference with the sensors/instrumentation. At relatively large geometric scales, modeling the full turbulence spectrum is difficult. The lack of large-scale turbulence (low-frequency content) can significantly impact the flow fluctuation around the test objects and may underestimate the peak loads that cause failure at full-scale.

To further address the scale issues, the LSU WISE research team is working on stages to build state-of-the-art open-jet testing capabilities to permit aerodynamic/aeroelastic testing at larger model sizes, compared to their counterpart wind tunnel models, with lower blockage effects, which enables better accuracy of testing with higher resolutions. While buildings with architectural features such as shingles, a roof, tiles, balconies, and soffits are difficult to replicate in small-scale models, larger test models will capture the intricate flow separation, vortex generation, and flow re-attachment phenomena at higher resolution, which will improve accuracy.

Figure 2 shows photographs of small and large-scale open-jet simulators at LSU–Phase 1 of an intensive wind, rain and wave (WRW) testing facility. The LSU WISE research team built a small-scale open-jet wind engineering testing facility (Figure 2-a). The small-scale open-jet was recently calibrated to generate wind velocity profiles that mimic wind characteristics over open and suburban terrain. With an adjustable planks mechanism, different wind profiles can be physically simulated. In addition, this lab has cobra probes, load cells, laser displacement sensors, and a 256-channels pressure scanning system. A Laser-Doppler Velocimetry measuring system is available in addition to High Resolution Digital Photography capabilities for flow visualization. Also, six component sting balances, traversing systems, and computer with data acquisition units are available.

LSU is now building Phase 1 of a larger wind and rain testing facility. Phase 1 permits generating wind flows at a relatively high Reynolds number over a test section of 4m x 4m (Figure 3-b). This will permit executing wind engineering experiments at relatively large scales. This facility strengthens the research capabilities of the WISE research program at LSU. The facility will enable researchers from LSU and the globe to test their research ideas, to expand knowledge leading to innovations and discovery in science, hurricane engineering, and materials as well as structures disciplines, to build the more resilient and sustainable infrastructure. Potential applications include, but are not limited to, wind turbines, solar panels, residential homes, large roofs, high-rise buildings, transportation infrastructure, power transmission lines, etc.



(a) **(b)**

Figure 2: *A new open-jet simulator at LSU; (a) small-scale with velocity and pressure transducers—1. General view of the open-jet facility; 2. Instrumented test building; 3. ZOC miniature electronic pressure scanning modules; 4. Three-component velocity Cobra probe; 5. RADBASE data acquisition unit; 6. ScanTel and Turbulent Flow software installed on a computer for online recording and processing of flow and pressure data during testing; and (b) larger version of the LSU open-jet simulator.*

DEPARTMENT HIGHLIGHTS

VEHICLE OF THE FUTURE?

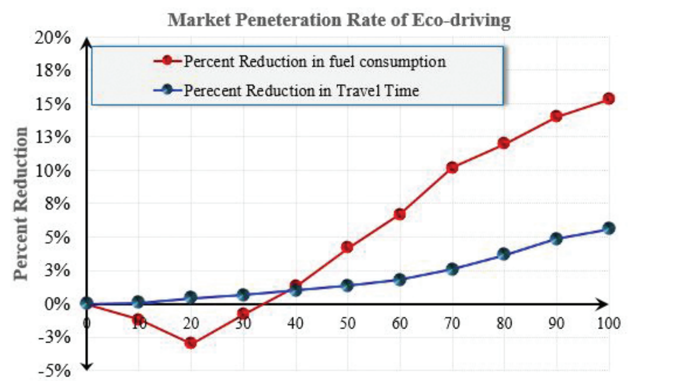
Connected/Autonomous Vehicles (CAVs) are expected to hit the ground running in the near future. Once fully deployed, CAVs are expected to trigger a technological revolution that will fundamentally alter the lifestyle of society, the automobile industry, and transportation research. In an early response to this, LSU researchers have been working over the past six years to develop and refine applications that can be integrated with CAVs to enhance driving safety and provide more environmentally friendly transportation systems.

Recently, LSU researchers were able to develop eco-driving applications for semi-actuated signalized intersections. Eco-driving applications guide CAVs approaching an intersection to pass the traffic signal without stopping by regulating their speed. Developing eco-driving applications for fixed-timing signals is straightforward because the signal cycle length is fixed. Developing these applications for actuated signals is more challenging due to the variations in the cycle length in response to vehicle actuations and the possibility of skipping certain traffic signal phases entirely.

However, Saleh Mousa, a researcher and PhD student at LSU, said, “The public and decision-makers should also be aware of the tentative adverse impacts of the technology in the early stages of deployment of CAVs.”

Vehicle Simulator at LSU

For instance, based on simulation results, it was found that applying eco-driving technology at Market Penetration Rates (MPR) of CAVs of less than 35% would, in fact, result in an increase in total fuel consumption. This negative impact at low MPR rates is attributed to aggressive lane changing and passing maneuvers performed by traditional vehicles as they follow a CAV under eco-driving control. Not understanding the reason for slowing down, regular uncontrolled vehicles



Percent Reductions in Fuel Consumption and Travel Time for different Eco-driving MPR

are likely to pass a CAV and cut into gaps ahead. For MPR values above 35%, the impacts of eco-driving applications become positive as more vehicles follow fuel-saving tactics and the opportunity for uncontrolled vehicles to oppose their behavior is reduced. As shown in the figure below, when all vehicles are controlled by eco-driving applications, a reduction of as much as 15% in fuel consumption and 6% in travel time can be realized.

Research conducted at LSU within the CAV area has not been limited to applications regarding optimum vehicle behavior at signalized intersections. They have also used the driving simulator in the Department of Civil and Environmental Engineering to assess the behavior of drivers when their CAV suddenly exits self-drive mode and forces the driver to regain manual control. Much research is needed to determine how quickly manual control can be regained, and what factors affect effective vehicle control. Below is a driver navigating the simulated environment in experiments conducted at LSU.

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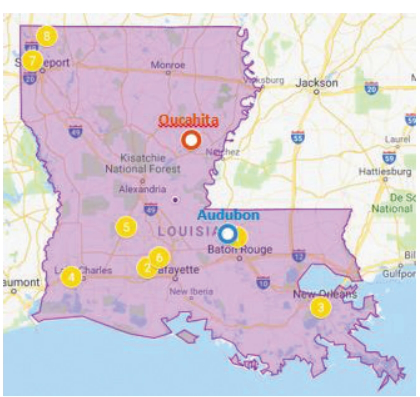
DEPARTMENT HIGHLIGHTS

SENSING OUR TRANSPORTATION INFRASTRUCTURE

There are several ways for understanding the behavior and performance of structural systems. One of them is by developing analytical or numerical models, which nowadays can be extremely complex because of the advancements in computational tools and platforms. These models often need to be validated and/or calibrated using experimental results from tests conducted in the laboratory or in the field. Laboratory testing has been the dominant experimental research tool for decades. Recently, field testing has been gaining acceptance and a larger share of testing activities. There are several reasons for this new trend. Laboratory testing is often constrained by available resources such as lab space and testing machine capacities, among other things. Therefore, researchers often use scaled-down laboratory specimens of actual structures or structural elements.

Furthermore, many details are often idealized in laboratory testing, which is an important, and sometimes necessary, simplification to be able to conduct the test and interpret the results. Alternatively, field testing is conducted on actual structures in service. In other words, they are full-scale specimens with no idealizations involved: "what you test is what is built." The purpose of field testing varies widely based on project goals. The whole exercise is often referred to as Structural Health Monitoring (SHM), especially when damage detection is involved. In the last 20 years, SHM and Nondestructive Testing (NDT) have matured enough that they have become essential tools that engineers use daily.



LSU CEE Professor Dr. Ayman Okeil had the opportunity through three projects sponsored by the Louisiana Transportation Research Center (LTRC) to apply SHM techniques for the purpose of evaluating and assessing the performance of transportation structures in Louisiana. The projects were spread all over Louisiana.

The first project started in 2008 to evaluate a new continuity detail that was employed in the John James Audubon project by the design-build team that won the project. A total of 66 sensors were installed on one of the approach bridge segments on the west side of the project. Data was collected for nearly five years and was used to understand the behavior of the new detail under live load and long-term effects (creep and shrinkage) in addition to temperature variations. More recently, a bigger effort was launched to understand a simpler continuity detail by using the new Ouachita River Bridge (LA-8) as a testbed for establishing the best practices in future bridges. The 20-span project was instrumented with 134 sensors from which data is still being collected. Both projects mainly focused on the long-term behavior of the bridges in addition to live load (trucks) effects that bridges are typically subject to.

The third project was different than the previous two. The objective of this project was to confirm the load carrying capacity of cast-in-place (CIP) reinforced concrete (RC) box culverts that would typically need to be load posted, i.e., size and weight of trucks that can travel on it must be limited. The Bridge Design Section of the DOTD selected eight CIP-RC box culverts all over Louisiana for the project. The culverts

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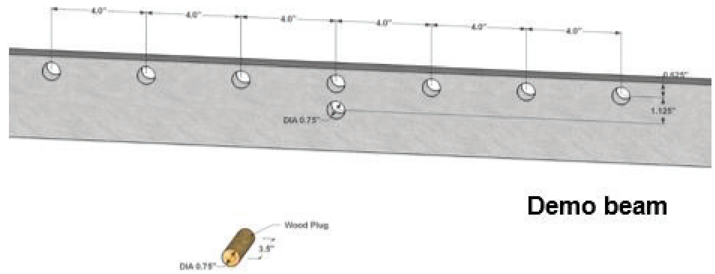
Sensor positions inside culvert

were chosen to have low earth fill (< 2 feet) over them because such low fills are more critical since wheel loads get distributed over a narrower area of the culvert. Results from the field tests showed that all culverts were safe for design loads and that load posting was not necessary. This finding triggered additional work to identify how load rating procedures can be improved to reflect the observed behavior that current design codes do not capture.

Dr. Okeil's belief in the importance of SHM is not limited to research and practice. He believes that it is important to prepare our current students for the future practice of civil engineering by providing them with proper training in structural health monitoring. In collaboration with Dr. Vijaya "V.J." Gopu, associate director of external programs at the Louisiana Transportation Research Center (LTRC), and LSU CEE Professor Emeritus Dr. Roger Seals, Okeil was able to secure a grant from the National Science Foundation (NSF) for that purpose. The $337,312 grant supports the development of educational modules to introduce the fundamentals as well application of SHM in existing analysis and design courses. The modules have been introduced in two Louisiana institutions—LSU and UL-Lafayette—and four partner institutions—Virginia Tech, Case Western Reserve University, University of North Florida, and Tuskegee University. In one of the developed modules, students are introduced to the principles of SHM through a hands-on demonstration before and after damaging a beam specimen by drilling holes at critical locations. Assessment of the effectiveness of the pedagogical model developed through this project is currently under way. It is expected that a broader dissemination effort will take place next year to inform the wider civil engineering community of what has been accomplished at LSU.



Demo beam

Demo beam prior to loading

Sensors installed on demo beam

LSU, THREE INTERNATIONAL UNIVERSITIES JOIN TOGETHER TO RESEARCH ADDITIVE MANUFACTURING

The Polish National Academic Exchange Agency recently contributed $100,000 to the ITHACA Project, a joint scientific project related to additive manufacturing between LSU, Lorraine University in France, Derby University in England, and IPPT from the Polish Academy of Sciences.

The ITHACA Project will be implemented from December 2018 to November 30, 2020, and the results obtained will be presented at joint seminars and conferences, including the Fourth International Conference in Damage Mechanics, which will be held in Baton Rouge in May 2020. Over the course of the project, researchers will exchange findings, visit each other's institutions, hold seminars, and jointly publish academic articles on the topic, thereby opening up new avenues of scientific collaboration between LSU and its European counterparts.

The main researchers involved are LSU Civil and Environmental Engineering Chair George Voyiadjis, IPPT Professor Zbigniew Kowalewski, IPPT Professor Tomasz Libura, Lorraine Professor Alexis Rusinek, and Derby Professor Paul Wood.

LSU IPPT PAN UNIVERSITÉ DE LORRAINE UNIVERSITY OF DERBY

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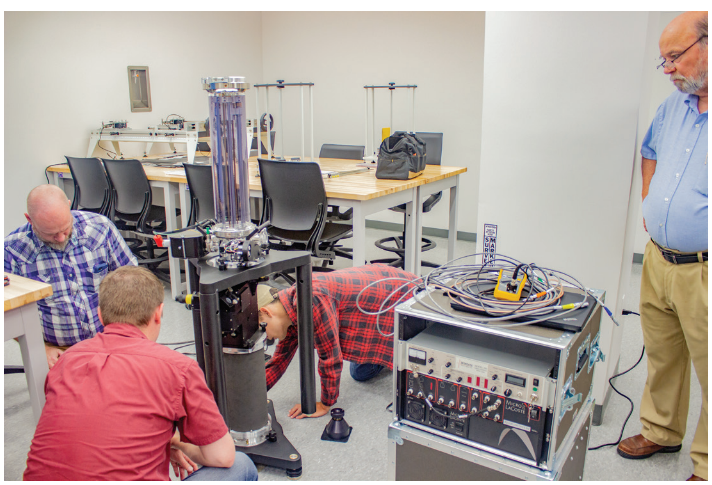
DEPARTMENT HIGHLIGHTS

MAJOR GRANT FOR THE CENTER OF GEOINFORMATICS

From the National Oceanic and Atmospheric Administration to support and enhance Regional Geospatial Modeling

LSU's Center for GeoInformatics (C4G) in its role as the Louisiana Spatial Reference Center (LSRC) has been awarded a $3.1 million grant over the next five years (2018-2023) from the National Oceanic and Atmospheric Administration (NOAA) for their support in the Regional Geospatial Modeling. The principal investigator and project director is Boyd Professor George Z. Voyiadjis, C4G director with co-investigators Randy L. Osborne, Clifford J. Mugnier, and J. Anthony Cavell. Larry Dunaway and Jon Cliburn round out the investigating team.

The LSRC's grant is in collaboration with a continuing five-year Gulf Coast-wide partnership among Mississippi, Texas, Louisiana, Florida and Alabama, to support the improvement and modernization of NOAA's National Spatial Reference System (NSRS). Key to these efforts will be the collection of accurate, precise, and consistent geospatial data to improve regional geospatial models and to coordinate the use of this geospatial data by users to improve the NSRS for the states bordering the northern Gulf of Mexico. Partnership outreach efforts will bring awareness, access, and education to users of the NSRS. The geospatial data resources produced through the partnerships will improve NSRS Height Modernization efforts across the entire northern Gulf of Mexico coast.



Setup of C4G's new $400K Micro-g LaCoste FG5-X Absolute Gravity Meter on the Baton Rouge – AA gravity mark in the CEE Materials Lab located in Patrick F. Taylor Hall.

C4G staff Jon Cliburn & Larry Dunaway participated in the 2018 North American Comparison of Absolute Gravimeters event heald at NOAA's Table Mountain Gravity Observatory in Longmont, CO.

The LSRC proposed a unified, regional partnership that will focus on the following objectives as the Louisiana portion of the broader proposal package submitted by the University of Southern Mississippi.

LSRC will work to enhance the infrastructure of geodetic control, coastal remote sensing data, terrestrial gravity measurements and other physical datasets. Various means will be used, which include deploying two Scintrex CG-5 Relative Gravity Meters that were purchased at a cost of $100,000 each under prior grants, one from a NOAA/NGS height modernization grant and another from an LSU Board of Regents grant. C4G's new self-funded $400,000 Micro-g LaCoste FG5-X Absolute Gravity Meter will be deployed to collect terrestrial gravity measurements at the C4G's Continuously Operating Reference Stations (CORS), NSRS benchmarks, and LSRC eccentric benchmarks, which will allow LSRC to improve the geodetic modeling for future datums and NSRS modernization.

Several newly acquired pieces of equipment will be used for these observations. The Scintrex Trident Tripod, in conjunction

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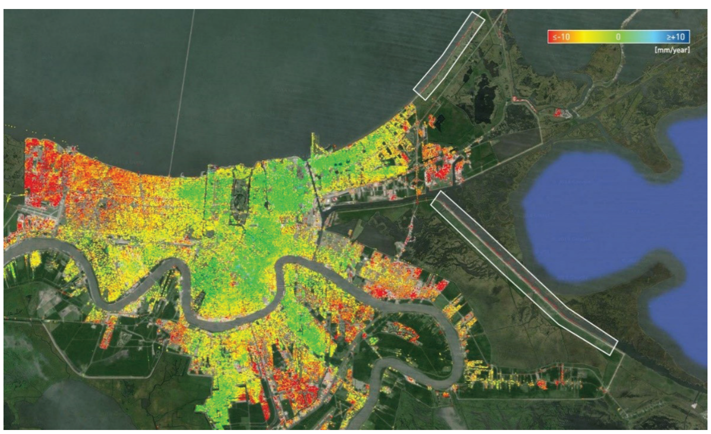
with C4G's CG-5 Relative Gravity Meters, will be used to observe the Gravity Gradient by accurately positioning the gravity meter at three predetermined levels for quick and precise measurements. Through the NOAA grant, the LSRC will acquire a $100,000 Digital Zenith camera in the first year of this grant from the Institute of Geodesy and Geoinformatics located at the University of Latvia, and will use this new instrument to measure the vertical deflection at CORS sites. The deflection of the vertical is a measure of how far the gravity direction has shifted, caused by local anomalies, which helps increase the accuracy of local surveys of the Earth's gravity field.

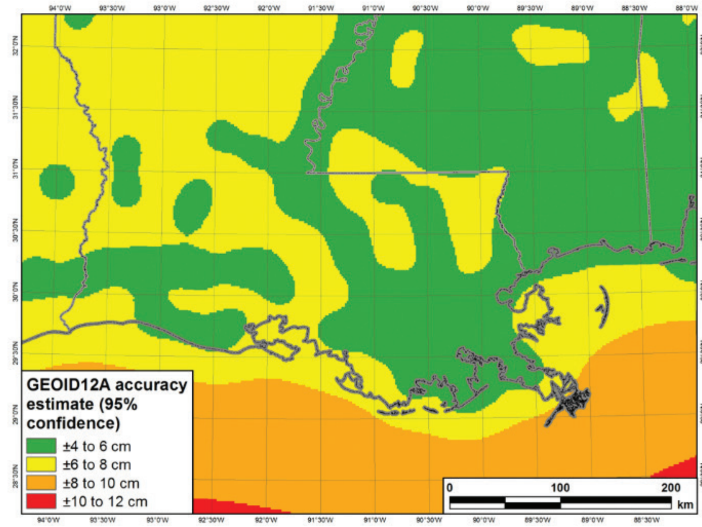
LSRC will also collaborate with NASA's Jet Propulsion Lab (JPL) in order to investigate targeting methods using InSAR to track regional subsidence to help develop guidelines and tools to access geodetic control and to manipulate and analyze geodetic data.



Typical InSAR image taken of the Greater New Orleans area.

LSRC continues to maintain the existing geospatial data clearinghouse it established to provide free access to information that includes CORS raw data, flood maps, satellite, aerial photography, digital elevation models (e.g., LiDAR, RADAR, and InSAR), and other relevant assets necessary for regional geospatial modeling.

The national goal is to develop models with accuracies better than 2 cm (3/4 in.). The dynamic nature of Louisiana's geology makes it an outlier when continental geodetic models are



NGS plot shows GEOID12a produces 95% confidence at ± 4 to 8 cm in Louisiana

developed, with many negative results for Louisiana. The LSU C4G has demonstrated the ability to observe precise terrestrial gravity, elevations and geometric relationships to the degree necessary for improving the geodetic models. Observing and possibly predicting subsidence in south Louisiana and along the Gulf Coast has been an acute challenge recognized since the 1950s, and becomes more acute with time. The NOAA grant seeks to build on the work of the LSU C4G that shows promise of bringing Louisiana and the Gulf Coast into the norm, permitting accurate geoid models, flood mapping, coastal studies, levee construction and public safety in general.

C4G was created in 2001 to build new research and services in geodesy and geoinformatics for the geodetic and geophysical communities. The C4G, in cooperation with NOAA's National Geodetic Survey (NGS), founded LSRC in 2002 as a partnership focused on a state-of-the-art positional infrastructure for the state of Louisiana and to provide technical leadership, training and access to positional data. LSRC is responsible for the network of GNSS control stations, a reliable spatial reference system in Louisiana (GULFnet). C4G maintains the GNSS Real Time Network (C4Gnet), established in 2007 to serve surveying, mapping, utilities, emergency response, agriculture, forestry, public safety, transportation, machine control for construction, environmental, and scientific research. – *Positioning Louisiana for the Future.*

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DEPARTMENT HIGHLIGHTS

RESEARCH EXPERIENCE IN GRAVIMETRIC GEOID MODELING AND ITS APPLICATIONS

In September, Dr. Ahmed Abdalla joined LSU's Center for Geoinformatics as an assistant research professor. Before joining C4G, Dr. Abdalla was a postdoc visiting scholar at Leibniz University of Hanover (LUH) for one year while working as an assistant professor at the University of Khartoum in Sudan. He received his PhD in surveying engineering with an emphasis on geodesy from the University of Otago, New Zealand, in 2013. He received his bachelor's in surveying engineering from University of Khartoum, Sudan, in 2003. He earned his master's in geodesy and geoinformatics from the Royal Institute of Technology (KTH) in Sweden in 2009, respectively. His main research focuses on the determination of high-resolution regional gravimetric geoid models using ground truth and satellite datasets such as terrestrial gravity, GPS and levelling data, and satellite data such as altimetry data, global geopotential models (GGMs) and digital elevation models (DEMs). His additional research includes interests in gravity modeling, geomatics, height systems, geodetic network adjustments and the analysis of errors. Dr. Abdalla acquired strong experience in geoid modeling through working under the guidance of expert leaders in geodesy in Sweden, New Zealand, and Germany. He computed geoid models over different countries such as Sudan/South Sudan, New Zealand, and Saudi Arabia. During his recent post doctorate at LUH, he optimized a new geoid model for Sudan and South Sudan to improve their accuracy. A significant improvement in accuracy (4-10 cm) was achieved compared to the pre-existing models. Dr. Abdalla will start processing and analyzing long-term GNSS time series data and will maintain his research work at C4G.

What is the geoid and why do we need it?

The geoid is defined as a surface that has overall equal potentials, which closely represents the mean sea level (MSL) where all vertical height measurements that are currently used in engineering are referred. The importance of geoid modeling stems from the need to have a precise and well-defined reference surface for geodetic vertical control. The high-quality results and accuracy of the global navigation satellite systems (GNSS) have shown a great interest and quick growth in using GNSS for engineering and research purposes. The GNSS provides 3D positioning data, which consists of 2D horizontal coordinates and a height in the vertical direction known as the ellipsoidal height, which conceptually differs from the MSL height (orthometric height or elevation). The ellipsoidal height is based on the ellipsoid surface, which is approximately assumed for earth fitting—different from elevation. This difference makes it incompatible with the orthometric height. Hence, the geoid is needed to convert the ellipsoid height to become an orthometric height, or elevation. The impact of integrating the geoid model with GNSS will increase the accuracy of measurements and determination of elevations.

Heterogeneous datasets for geoid modeling

The geoid can be computed by different methods using various mathematical expressions according to the famous Stokes integral formula, which employs the terrestrial gravity over the earth surface data. However, due to the lack of the gravity measurements over the earth's surface (Figure 1a), only area around the existing gravity data is truncated to compute the geoid. This truncation affecting the geoid accuracy is called the truncation error. Therefore, the global geopotential models are used to restore the far-zone effect on the truncated area as shown in Figure 1b.

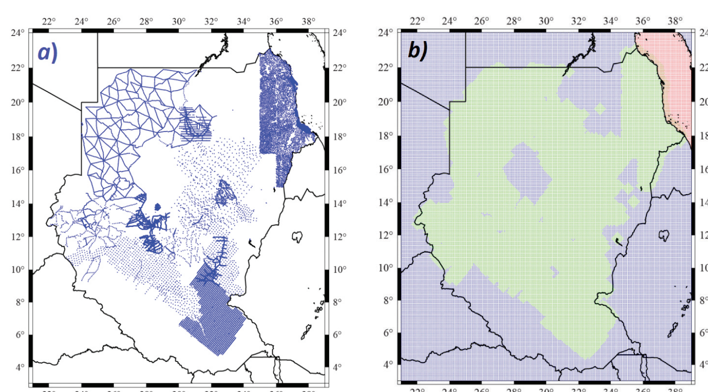

***Figure 1**: Left: Terrestrial gravity data over Sudan and South Sudan. Right: Combined gravity grid including terrestrial (green), GGM (blue), and altimetry (red) data.*

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One of the well-known geoid determination techniques is called remove-compute-restore (RCR), which implies the basic theoretical assumption of the geoid. The geoid is assumed to be a harmonic surface, meaning that all masses above the geoid have to be removed or reduced to the geoid surface. Based on that, the GGM and DEM are used to reduce truncation and topography effects on the geoid. The GGM is validated with the terrestrial gravity and GPS-leveling data for the best fit agreement as shown in Figure 2. RCR can also be applied within the context of the least-squares collocation (LLC) and Fast Fourier Transform (FFT).

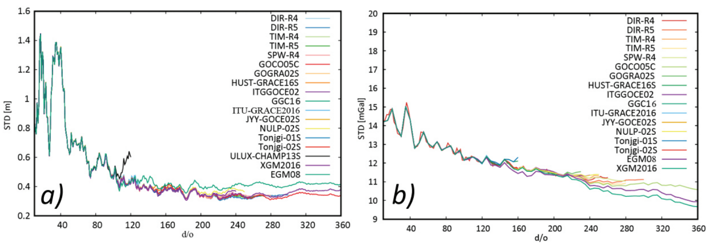

Figure 2: *GGMs validation vs GNSS-leveling data (a) and terrestrial gravity data (b)*

Figure 3a shows that the spherical radial basis functions (SRBFs) can be used to estimate the accuracy of the terrestrial gravity data. Stochastically, the geoid is also computed by modifying the Stokes formula by means of least-squares (LS), which efficiently shows high accuracy. The rigorous solution of the LS modification gives three coefficients, namely, bias, unbiased and optimum. The biased coefficients are obtained by direct LS inversion while the unbiased and optimum coefficients are obtained after applying regularization due to ill-posed inverse problem (see Figures 3.b and 3c). The LS

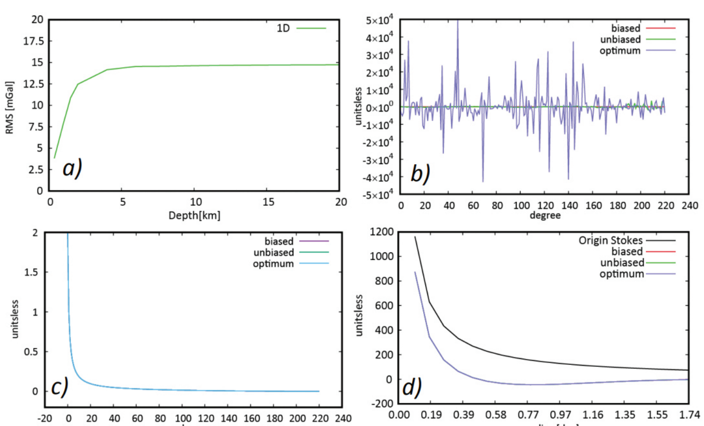

Figure 3: a) accuracy of terrestrial gravity, b) instable LS coefficients, c) regularized LS coefficients, d) original and LS-modified Stokes kernels.

coefficients minimize the errors of all the datasets used in the computation process, e.g. (terrestrial gravity, GGM and DEM) beside the truncation error as seen in Figure 3d.

In contrast to RCR, the terrestrial gravity data is directly used in LS modification and additional corrections associated to topography, ellipsoid, atmosphere and downward continuation of the gravity to the MSL are added later to the geoid solution. Figure 4 shows the geoid model of Sudan/South Sudan.

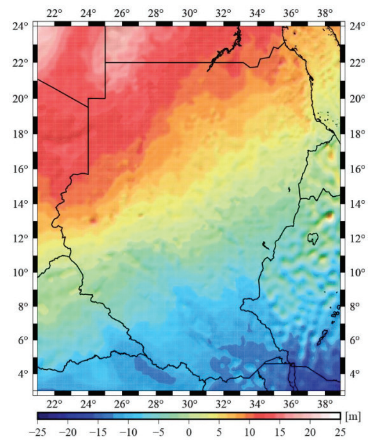

Figure 4: Gravimetric geoid model for Sudan/South Sudan (2017)

Geoid validation

The validation of the gravimetric geoid solution is conducted using local GPS-leveling data. The gravimetric geoid heights are compared to the geometrically-derived geoid heights from the GPS-levelling points over the area of study. The quality and density of the GPS-leveling are very important to realize the accuracy of the final geoid. Nevertheless, systematic errors are likely to propagate into both the gravimetric solution and the GPS-leveling data due to the different sources of errors in each dataset used in modelling and validation. Therefore, 4, 5 and 7-parameter models are used to remove these systematic errors.

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DEPARTMENT HIGHLIGHTS

LSU ASCE HOSTS 2018 LARGEST-EVER BAYOU REGION CAREER FAIR

In October, the LSU chapter of the American Society of Civil Engineers (ASCE) held the ASCE Bayou Region Career Fair, which included, for the first time, civil and environmental engineering students from LSU, McNeese State University, Southern University, the University of Louisiana-Lafayette, and the University of New Orleans.

In all, more than 200 students attended the event, which included a meet-and-greet at Walk-On's Bistreaux & Bar, a tour of Patrick F. Taylor Hall, and the career fair itself, which boasted 100 employers from 33 companies.

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