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Geospatial Discovery and Innovation
in the Era of CyberGIS and Machine Intelligence

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United Nations World Geospatial Information Congress
Deqing, Zhejiang, China
November 19, 2018

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GIS

- Systems
- Science
- Services
- Society
- Synthesis
- Geo and spatial are special

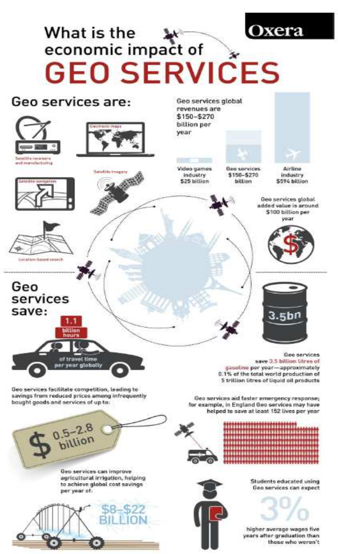

Image source: http://www.oxera.com/Oxera/media/Oxera/downloads/reports/What-is-the-economic-impact-of-Geo-services_1.pdf

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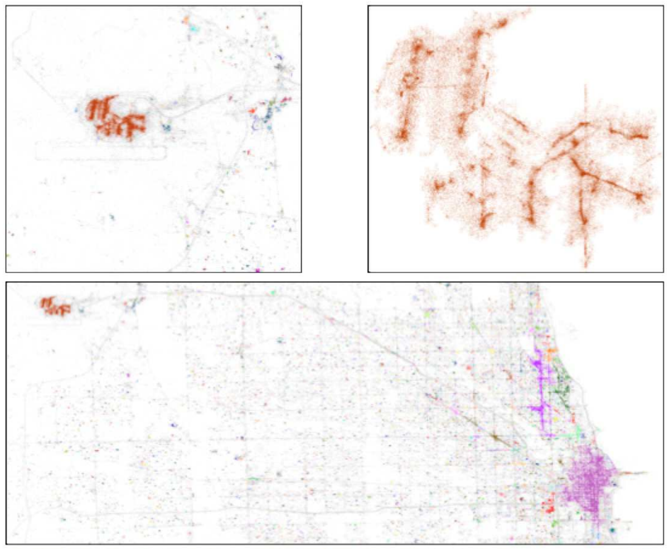

Image courtesy of Dandong Yin @ UIUC's CyberGIS Center

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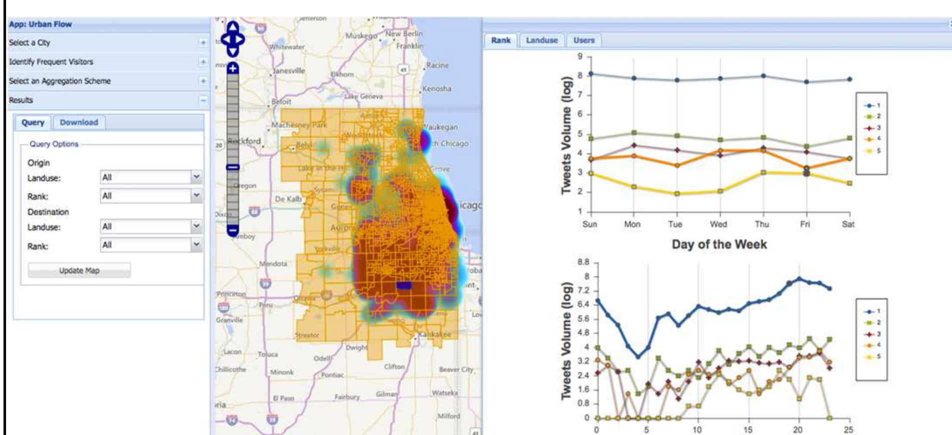
UrbanFlow for Mapping Urban Dynamics



- Soliman, A., Soltani, K., Yin, J., Padmanabhan, A., and Wang, S. (2017) "Social Sensing of Urban Land Use Based on Analysis of Twitter Users' Mobility Patterns". *PLOS ONE*, DOI: 10.1371/journal.pone.0181657
- Soltani, K., Soliman, A., Padmanabhan, A., and Wang, S. "UrbanFlow: Large-scale Framework to Integrate Social Media and Authoritative Landuse Maps". In: *Proceedings of the 2016 Annual Conference on Extreme Science and Engineering Discovery Environment (XSEDE'16)*, Miami, Florida, USA, July 17 – 21, 2016

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Geospatial Big Data

Volume, Velocity, Variety, Variability, Veracity, Value, etc.

- **Heterogeneous**
  - Syntactic
  - Semantic
- **Dynamic**
  - Spatial and temporal
  - E.g. social media
- **Massive**
  - Produced by individuals
  - Accessible to individuals
- **Large-scale**
  - Global coverage
- **Fine granularity**
  - Individual-level
  - High-resolution
- **Distributed access**
  - Interoperability
  - Privacy
  - Security

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The Free Encyclopedia

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CyberGIS

From Wikipedia, the free encyclopedia

CyberGIS, or **cyber geographic information science and systems**, is an interdisciplinary field combining cyberinfrastructure, e-science, and geographic information science and systems (GIS). CyberGIS has a particular focus on computational and data-intensive geospatial problem-solving within various research and education domains. The need for GIS has extended beyond traditional forms of geographic analysis and study, which includes adapting to new sources and kinds of data, high-performance computing resources, and online platforms based on existing and emerging information networks. The name cyberGIS first appeared in Geographic Information Science literature in 2010.[1] CyberGIS is characterized as digital geospatial ecosystems. These systems are developed and have evolved through heterogeneous computing environments (see CyberGIS Supercomputer below), as well as human communication and information environments. CyberGIS can be considered a new generation of geographic information systems (GIS). These systems are based on advanced computing and information infrastructure, which analyze and model geospatial data, providing computationally intensive spatial analysis, modeling, and collaborative geospatial problem-solving at previously unprecedented scales.[2]

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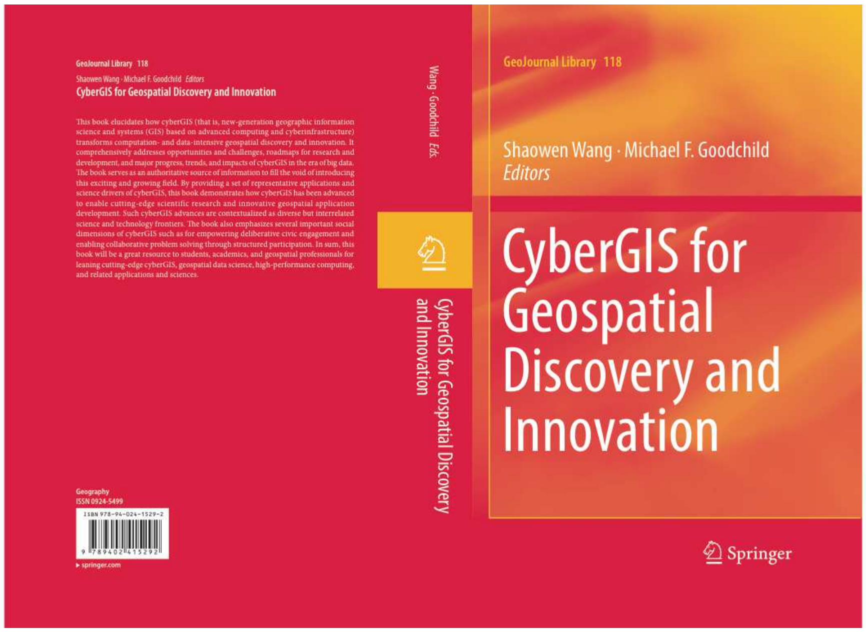

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Outline

- Applications and Science Drivers
- Science and Technology Frontiers
- Social Dimensions

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Applications and Science Drivers

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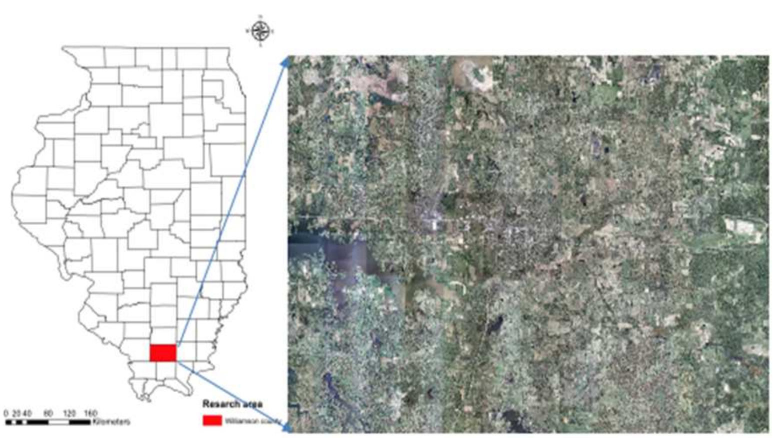
Wetland or Forest?



Xu, Z., Guan, K., Casler, N., Peng, B., and Wang, S. (2018) A 3D Convolutional Neural Network Method for Land Cover Classification Using LiDAR and Multi-Temporal Landsat Imagery”. *ISPRS Journal of Photogrammetry and Remote Sensing*, 144: 423-434

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USGS science for a changing world | The National Map

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3D Elevation Program (3DEP)

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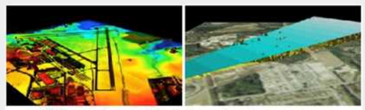
The National Map Home >> 3D Elevation Program (3DEP)

Introduction and Goals



LiDAR is used to detect potential obstacles that present hazards to air navigation.
Lidar is used to detect potential obstacles that present hazards to air navigation.

The 3D Elevation Program (3DEP) initiative is being developed to respond to growing needs for high-quality topographic data and for a wide range of other three-dimensional representations of the Nation's natural and constructed features. The primary goal of 3DEP is to systematically collect enhanced elevation data in the form of high-quality light detection and ranging (lidar) data over the conterminous United States, Hawaii, and the U.S. territories, with data acquired over an 8-year period. Interferometric synthetic aperture radar (IfSAR) data will be collected over Alaska, where cloud cover and remote locations preclude the use of lidar over much of the State. The 3DEP initiative is based on the results of the National Enhanced Elevation Assessment.

3DEP Data Acquisition Partnership Opportunities

FY18 USGS Broad Agency Announcement (BAA) for the 3D Elevation Program (3DEP)

Partnership Opportunities

The FY17/FY18 Broad Agency Announcement (BAA) for the 3D Elevation Program (3DEP) was released on August 16, 2017. The BAA provides detailed information on how to partner with the USGS and other Federal agencies to acquire high-quality 3D Elevation data. Information and contacts are available at Fed Biz Opps (Search for Reference Number: G17PS00746) and Grants.gov (Funding Opportunity Number: G17AS00116). Applicants may contribute funds toward a USGS lidar data acquisition activity via the Geospatial Products and Services Contracts or they may request 3DEP funds toward a lidar data acquisition activity where the requesting partner is the acquiring authority. Federal agencies, state and local governments, tribes, academic institutions and the private sector are eligible to submit proposals.

Public Webinars

The USGS hosts a set of public webinars each year to introduce the BAA opportunity to the broadest stakeholder community possible and to provide a summary of the application process.

Fiscal Year 2017 status of 3DEP quality data, as of August 2017

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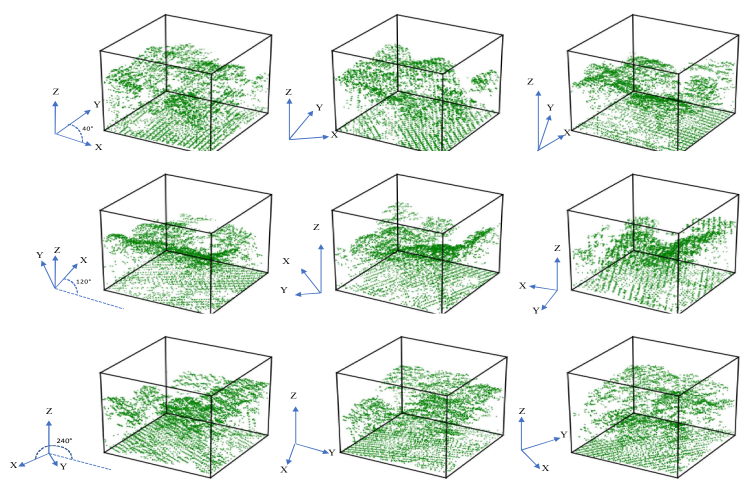

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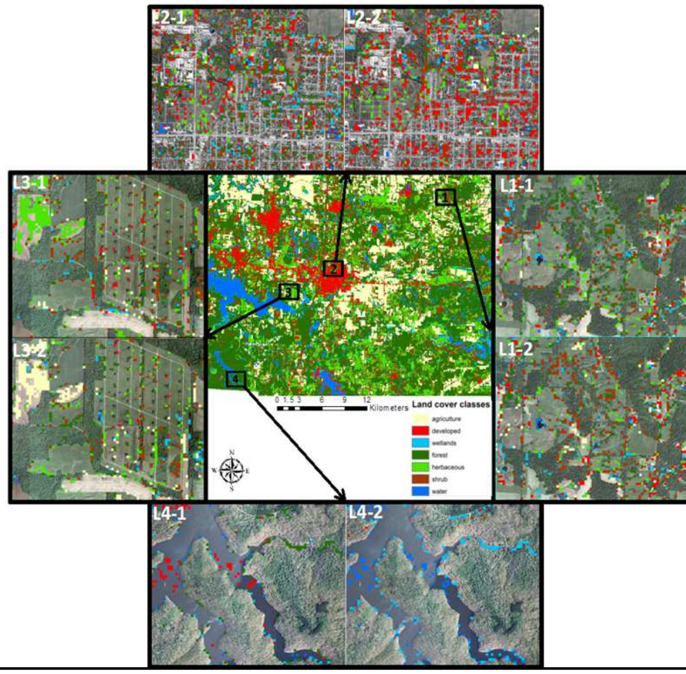

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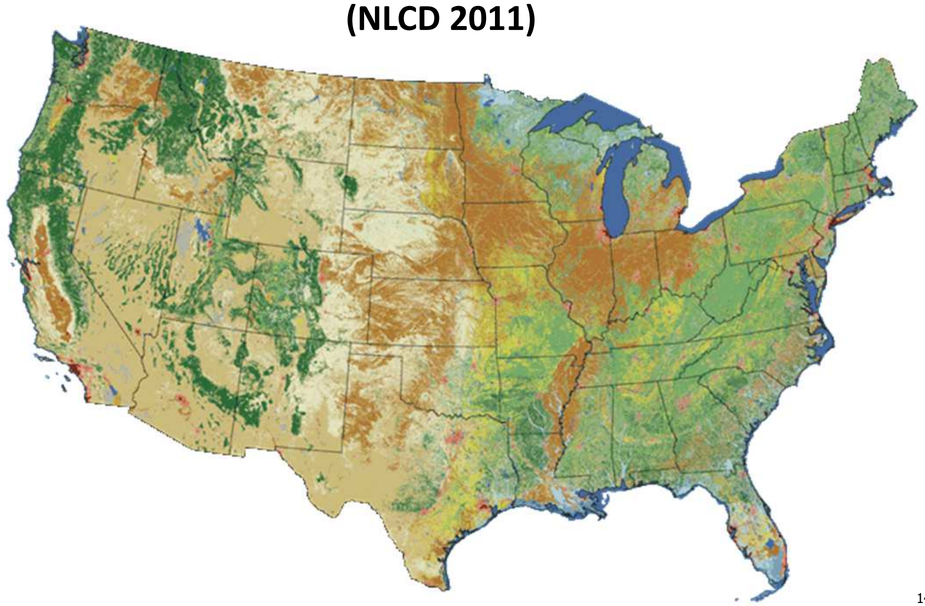
National Land Cover Database 2011 (NLCD 2011)



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Computation and Data Challenges

- Data preprocessing
  - 400+ CPU hours
    - LiDAR denoising
    - LiDAR data buffering and separation (heavy I/O)
    - Data aggregation (voxelization)
- Feature extraction process
  - 30 GPU hours with fixed parameters
    - 500 maximum epochs training with batch size of 256 (learning rate 0.001, momentum 0.9)
- Classification process
  - Without training data enlargement
    - Two-level grid search
    - Five-fold cross validation
    - 20,000 parameter combinations take 20 CPU hours
  - With training data enlargement
    - 9 times more than training without rotation

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Proceedings of the National Academy of Sciences of the United States of America

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> Current Issue > vol. 112 no. 46 > Justin M. McGrath, 14390–14395, doi: 10.1073/pnas.1509777112

CrossMark

An analysis of ozone damage to historical maize and soybean yields in the United States

Justin M. McGrath[a], Amy M. Betzelberger[b], Shaowen Wang[c,d], Eric Shook[e], Xin-Guang Zhu[a,f], Stephen P. Long[a,g,h,1], and Elizabeth A. Ainsworth[a,g,i,1]

Author Affiliations

Edited by Christopher B. Field, Carnegie Institution of Washington, Stanford, CA, and approved October 1, 2015 (received for review May 19, 2015)

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Significance

Although it has long been known that ground-level ozone (O_3) damages crops and reduces yield, there has never been an estimate of the total loss attributed to ambient O_3 for field-grown maize and soybean in the United States. Knowing the loss caused by this pollutant would be useful for projecting food supply and setting regulatory standards for pollutant emissions. Here we show that ambient O_3 has reduced maize and soybean yields in rain-fed fields by ~10% and 5%, respectively, based on historical observations from the past 31 y. Results suggest that air-quality regulations in the United States have been effective in reducing crop production losses to O_3, and indicate that further reductions in ground-level [O_3] would be beneficial in the United States and globally.

This Issue

November 17, 2015
vol. 112 no. 46
Masthead (PDF)
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A Fundamental Question

- What is the nature of computational intensity of geospatial analysis and modeling?
  - Why spatial is special?
- Comparable to
  - "What is the nature of computational complexity of an algorithm?"

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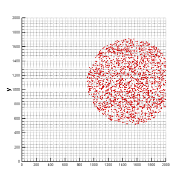
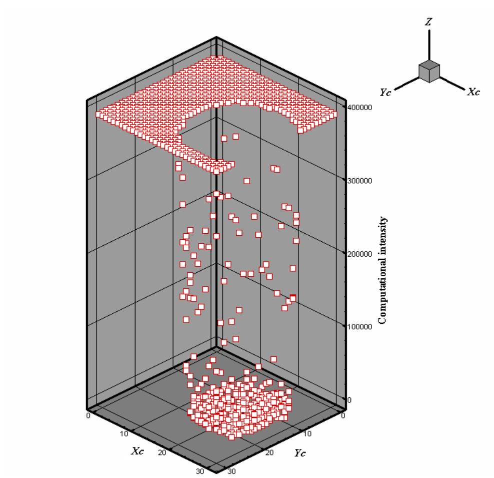
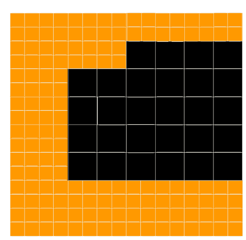
Spatial Computational Domain



Original dataset





Quadtree-based decomposition

Wang, S. and Armstrong, M. P. 2009. "A Theoretical Approach to the Use of Cyberinfrastructure in Geographical Analysis." *International Journal of Geographical Information Science*, 23 (2): 169-193

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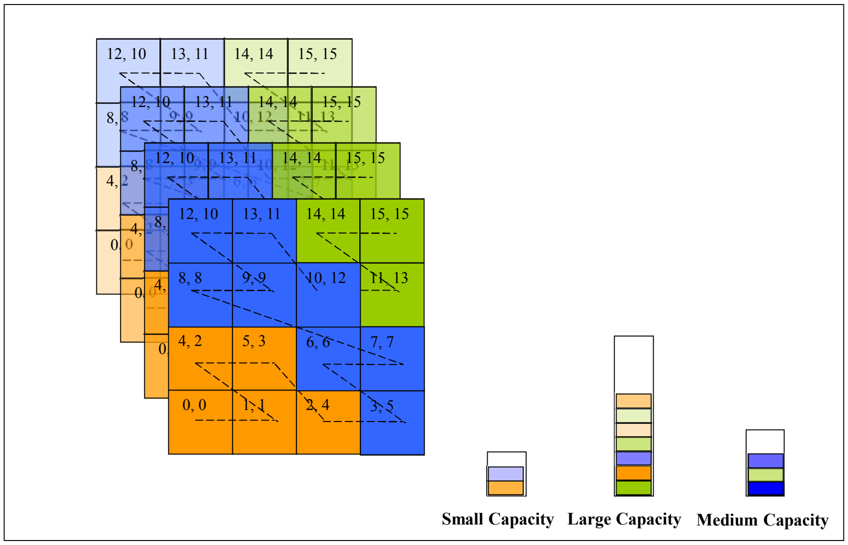
Divide and Conquer



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Science and Technology Frontiers

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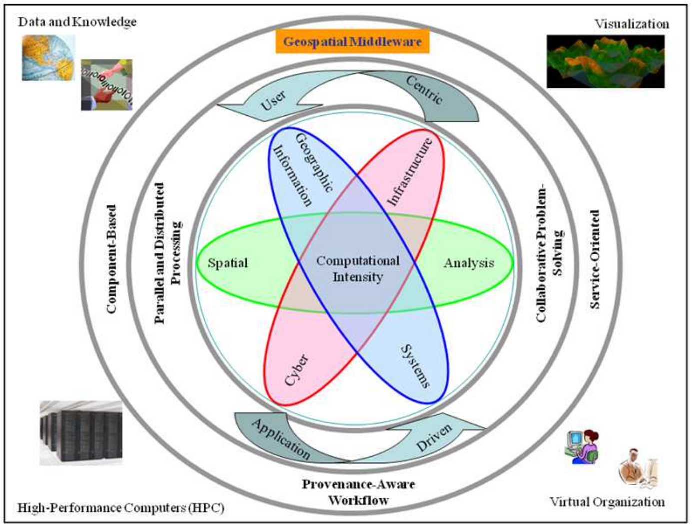
Integration, Interoperability, and Reproducibility at Scale



Wang, S. 2010. "A CyberGIS Framework for the Synthesis of Cyberinfrastructure, GIS, and Spatial Analysis". *Annals of the Association of American Geographers*, 100(3): 535-557

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NSF CyberGIS Software Project
~$4.8 million, Year: 2010-2017

Principal Investigator
- Shaowen Wang

Co-Principal Investigators
- Luc Anselin
- Budhendra Bhaduri
- Timothy Nyerges
- Nancy Wilkins-Diehr

Senior Personnel
- Michael Goodchild
- Sergio Rey
- Marc Snir
- David Tarboton
- E. Lynn Usery

Chair of the Science Advisory Committee
- Michael Goodchild

Project Manager
- Anand Padmanabhan

Project Staff
- ASU: Wenwen Li and Rob Pahle
- ORNL: Ranga Raju Vatsavai
- SDSC: Choonhan Youn
- UIUC: Yan Liu and Anand Padmanabhan
- Graduate and undergraduate students

Industrial Partner: Esri
- Steve Kopp and Dawn Wright

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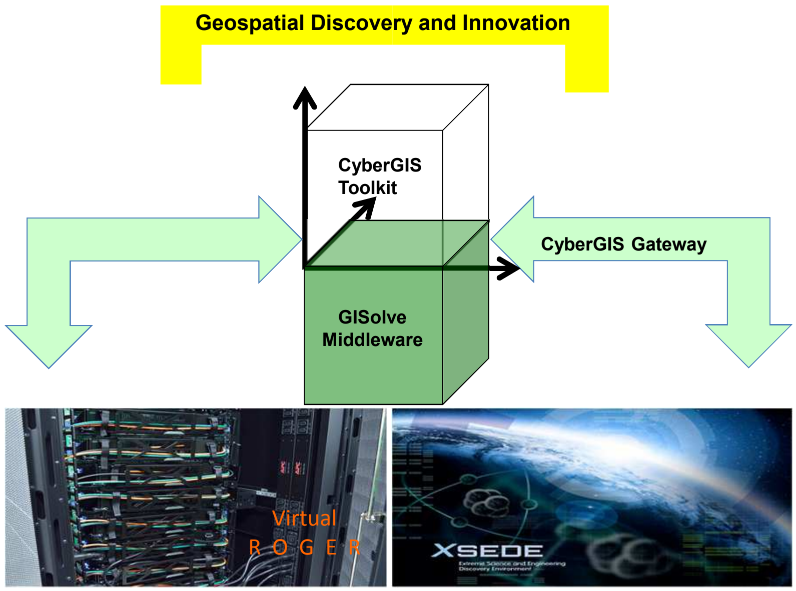

http://cybergis.illinois.edu

www.xsede.org

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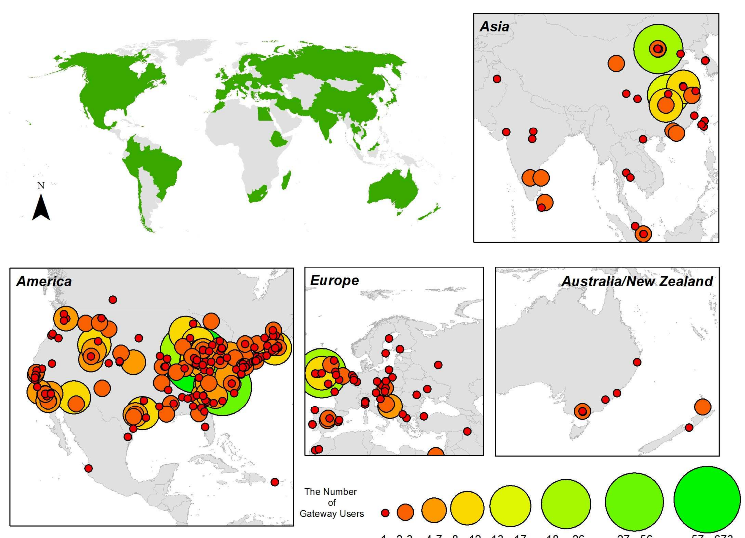

Wang, S., Liu, Y., and Padmanabhan, A. 2016. "Open CyberGIS Software for Geospatial Research and Education in the Big Data Era". *SoftwareX*, 5: 1-5

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CyberGIS Supercomputer – ROGER

(Resourcing Open Geospatial Education and Research)

- 5+ petabytes of raw disk storage with high input/output (I/O) bandwidth
- Solid-state drives for applications demanding high data-access performance
- Advanced graphics processing units for exploiting massive parallelism in geospatial data and computing
- Interactive visualization supported with a high-speed network and dynamically provisioned cloud computing resource

NSF MRI: Acquisition of a National CyberGIS Facility for Computing- and Data-Intensive Geospatial Research and Education

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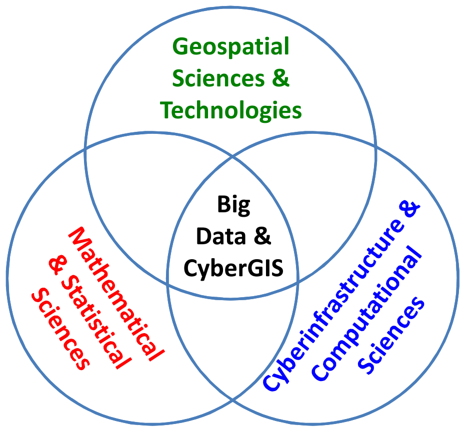
Geospatial Data Science



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Social Dimensions

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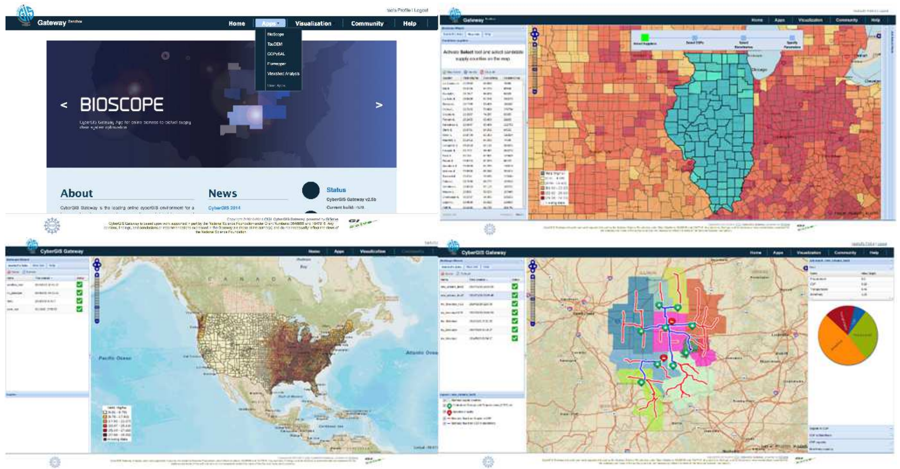
Collaborative Problem Solving and Decision Making



Hu, H., Lin, T., Liu, Y.Y., Wang, S., Rodriguez, L. (2015) "CyberGIS-BioScope: A Cyberinfrastructure-based Spatial Decision-Making Environment for Biomass-to-Biofuel Supply Chain Optimization". *Concurrency and Computation: Practice and Experience*, 27(16): 4437–4450

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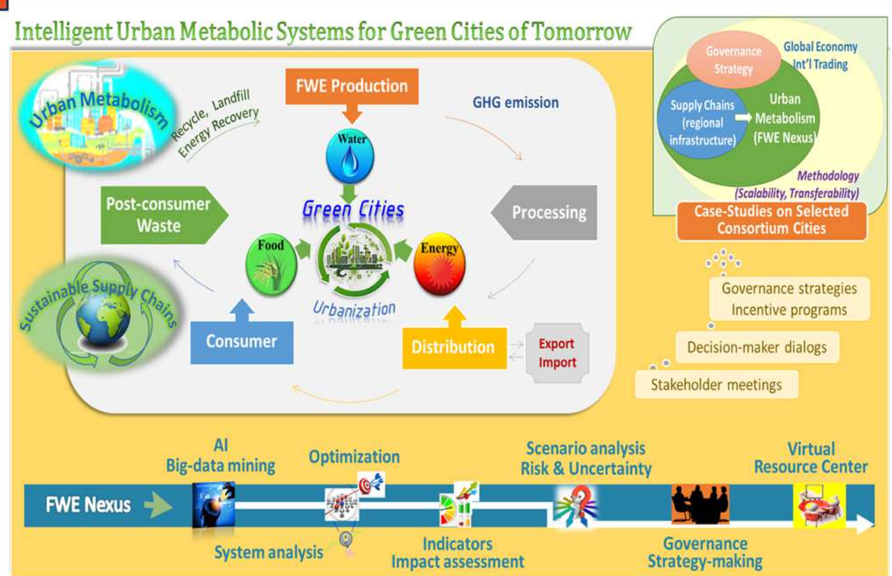

BELMONT FORUM

NSF

Rodriguez, Ouyang, and Wang (2018)

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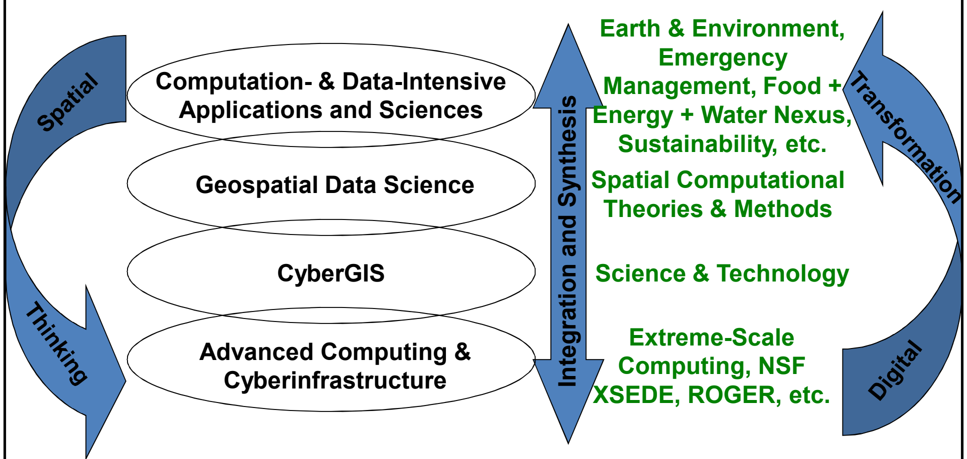
Vision



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Conceptualizing a National Geospatial Software Institute (GSI) http://gsi.cigi.Illinois.edu

Revolutionize discovery and innovation across many fields through synergistically advancing cyberGIS and geospatial inspired computing and data sciences

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Acknowledgments

- **Federal Agencies**
  - **Department of Energy's Office of Science**
  - **National Aeronautics and Space Administration**
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    - ACI-1429699
    - ACI-1551492
    - OAC-1743184
    - BCS-0846655
    - EAR-1239603
    - ICER-1833225
    - IIS-1354329
    - XSEDE
  - **US Department of Agriculture (USDA)**
  - **US Geological Survey (USGS)**
- **Industry**
  - **Environmental Systems Research Institute (Esri)**
  - **Nvidia**

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谢谢 - Thanks !

- **Comments / Questions?**
- **Email: shaowen@illinois.edu**