Spatiotemporal computing for enabling scientific research and engineering development: a GIS practice

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What is GIS?

A Short Personal Story

What is Spatial Computing, and Spatiotemporal Computing?

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http://cisc.gmu.edu/

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www.pnas.org/content/108/14/5498.abstract

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

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> Current Issue > vol. 108 no. 14 > Chaowei Yang, 5498–5503

Using spatial principles to optimize distributed computing for enabling the physical science discoveries

Chaowei Yang[1], Huayi Wu, Qunying Huang, Zhenlong Li, and Jing Li

Author Affiliations

Edited by Michael Goodchild, University of California, Santa Barbara, CA, and approved December 14, 2010 (received for review August 15, 2009)

Abstract

Contemporary physical science studies rely on the effective analyses of geographically dispersed spatial data and simulations of physical phenomena. Single computers and generic high-end computing are not sufficient to process the data for complex physical science analysis and simulations, which can be successfully supported only through distributed computing, best optimized through the application of spatial principles. Spatial computing, the computing aspect of a spatial cyberinfrastructure, refers to a computing paradigm that utilizes spatial principles to optimize distributed computers to catalyze advancements in the physical sciences. Spatial principles govern the interactions between scientific parameters across space and time by providing the spatial connections and constraints to drive the progression of the phenomena. Therefore, spatial computing studies could better position us to leverage spatial principles in simulating physical phenomena and, by extension, advance the physical sciences. Using geospatial science as an example, this paper illustrates through three research examples how spatial computing could (*i*) enable data intensive science with efficient data/services search, access, and utilization, (*ii*) facilitate physical science studies with enabling high-performance computing capabilities, and (*iii*) empower scientists with multidimensional visualization tools to understand observations and simulations. The research examples demonstrate that spatial computing is of

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vol. 108 no. 14
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Published online before print March 28, 2011, doi: 10.1073/pnas.0909315108
PNAS **April 5, 2011** vol. 108 no. 14 **5498-5503**

Classifications

Spatial Cyberinfrastructure
Special Feature
Research Articles
Physical Sciences
Computer Sciences

Access

- Abstract
- Full Text (HTML)
- Full Text (PDF)
- Figures Only

GIS Day,

includes about 100TB storage
and 10TFlops computing power
and the connection to

Microsoft

Dust Storm Hazards

- **Illness & Diseases**
- **Traffic & Car accidences**
- **Air Pollution**
- **Ecological System**
- **Desertification**
- **Global/regional Climate**

Phoenix Dust Storm a "100-Year Event“, 2011, July 5th

Dust Storm eScience Infrastructure

GEORGE MASON Center of Intelligent Spatial Computing for Water/Energy Science

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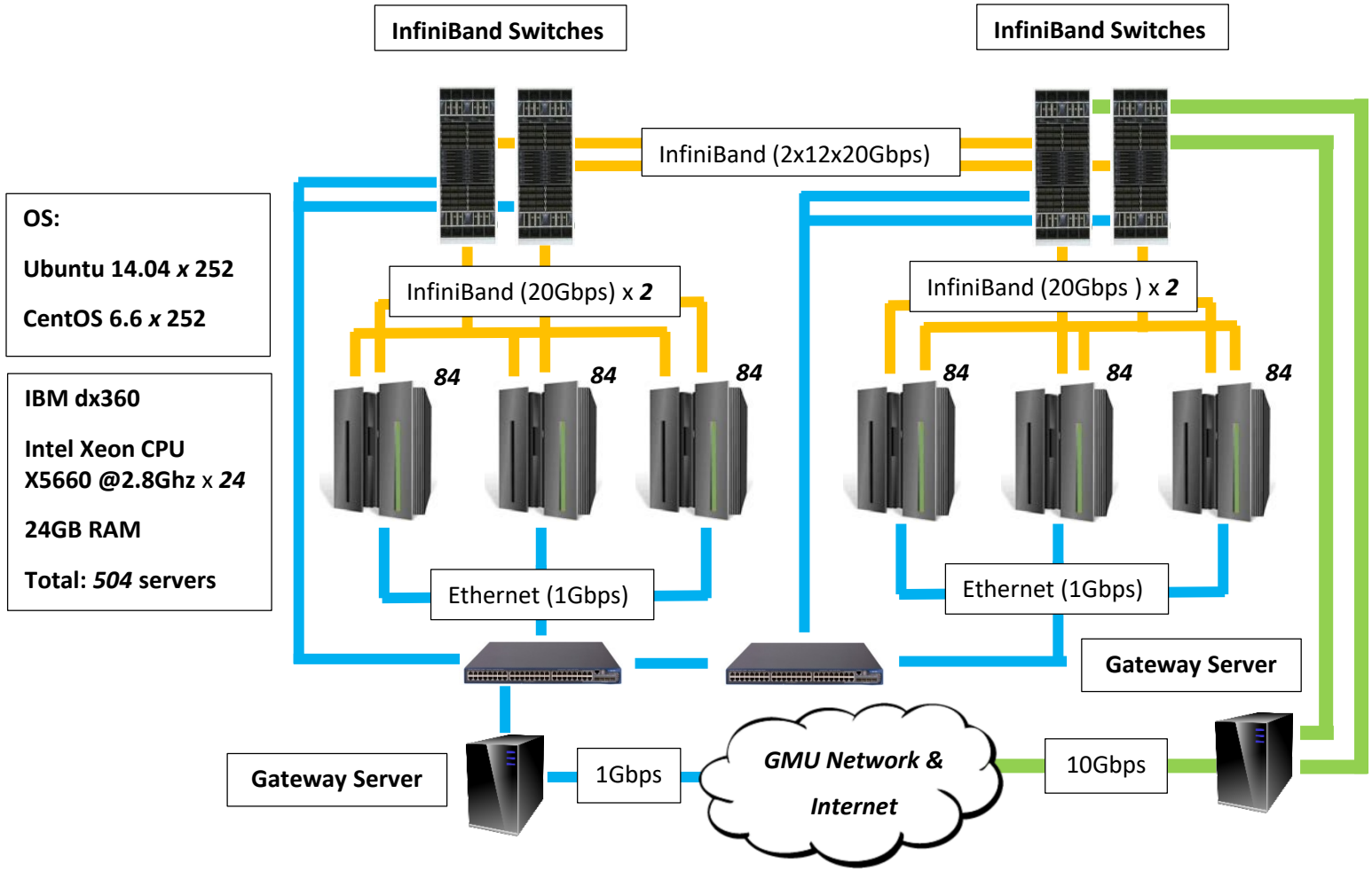
Put us in the Global Context

An Academic Geospatial Cloud Environment: Physical Infrastructure and Network Configuration



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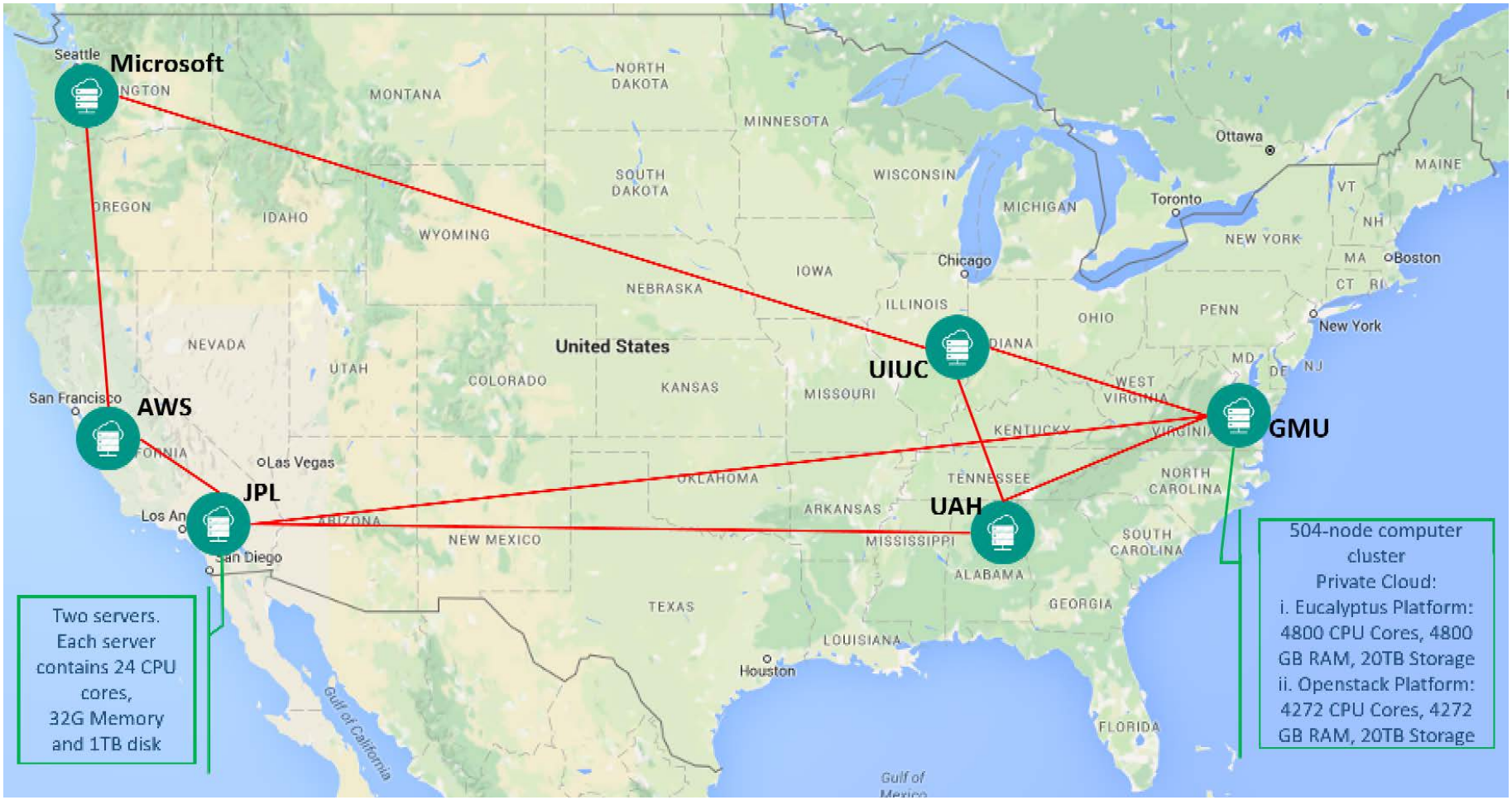
GeoCloud: A national big data cloud



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Leveraging Global Computing Resources

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A Practical A

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空间云计算——应用与实践

Spatial Cloud Computing
A Practical Approach

Chaowei Yang Qunying Huang 著
李 锐 黄 蔚 金宝轩 译

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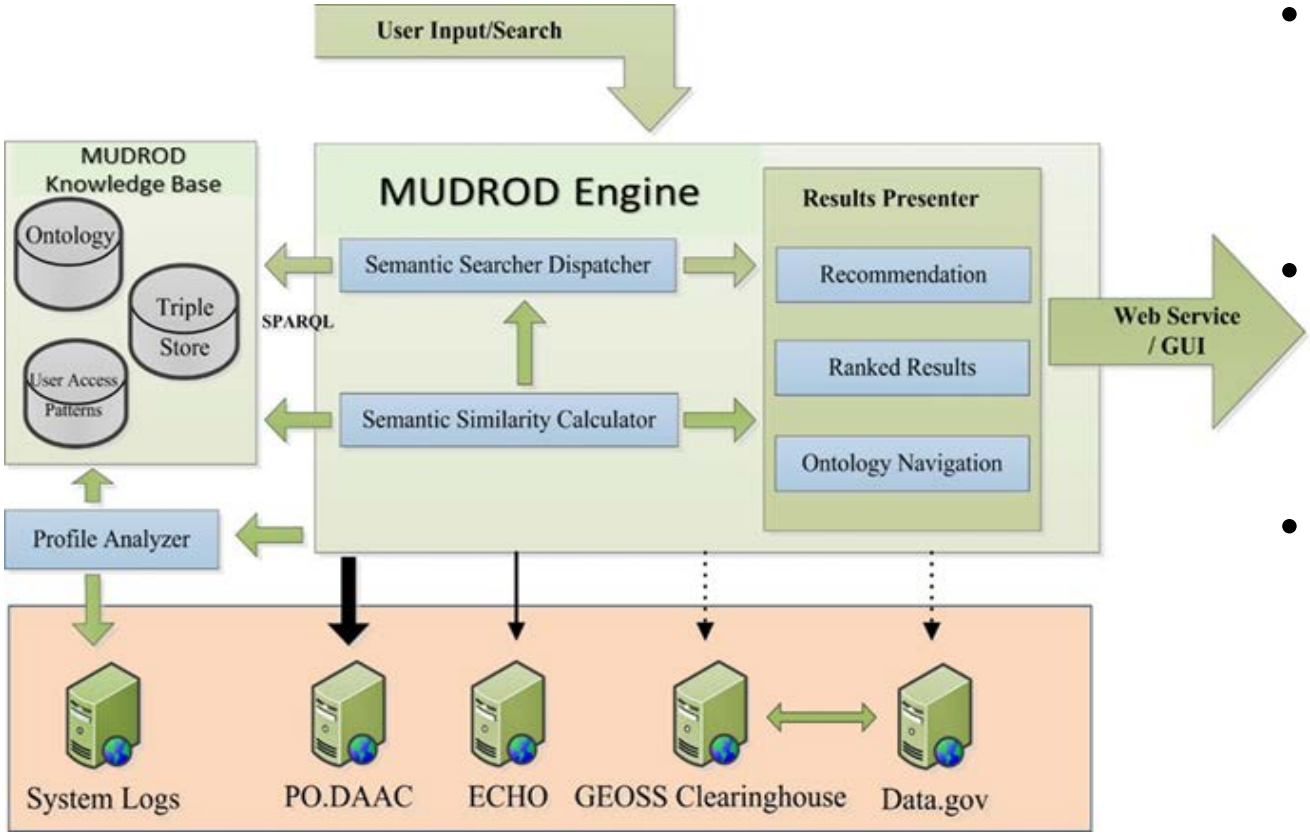
Building and Utilizing Spatiotemporal Knowledge Base?

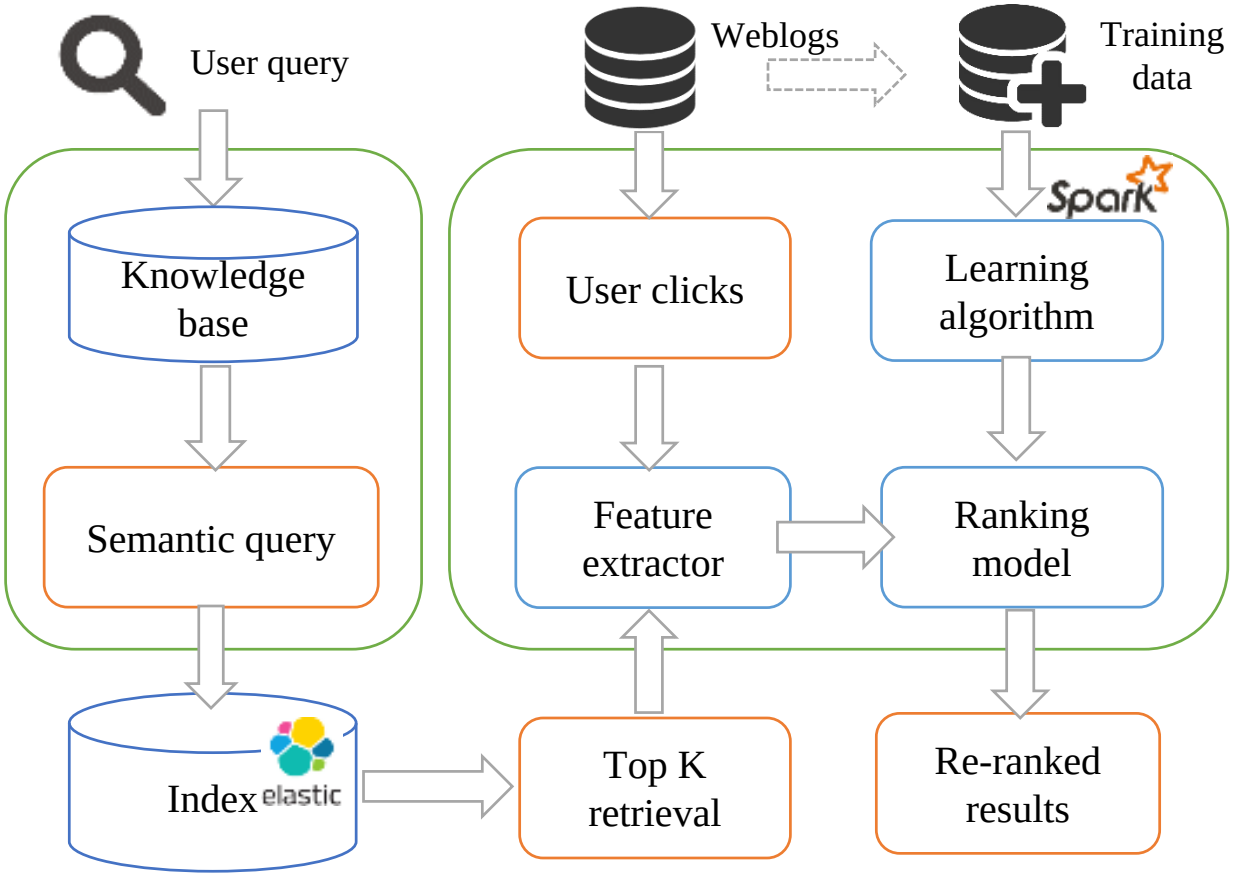
Smart Data Discovery

Architecture



- All of these (except for training) can be finished within 2 seconds
- None of the open source mainstream ML library provide any ranking algorithm
- Implemented it by ourselves with the aid of Spark MLlib

Architecture



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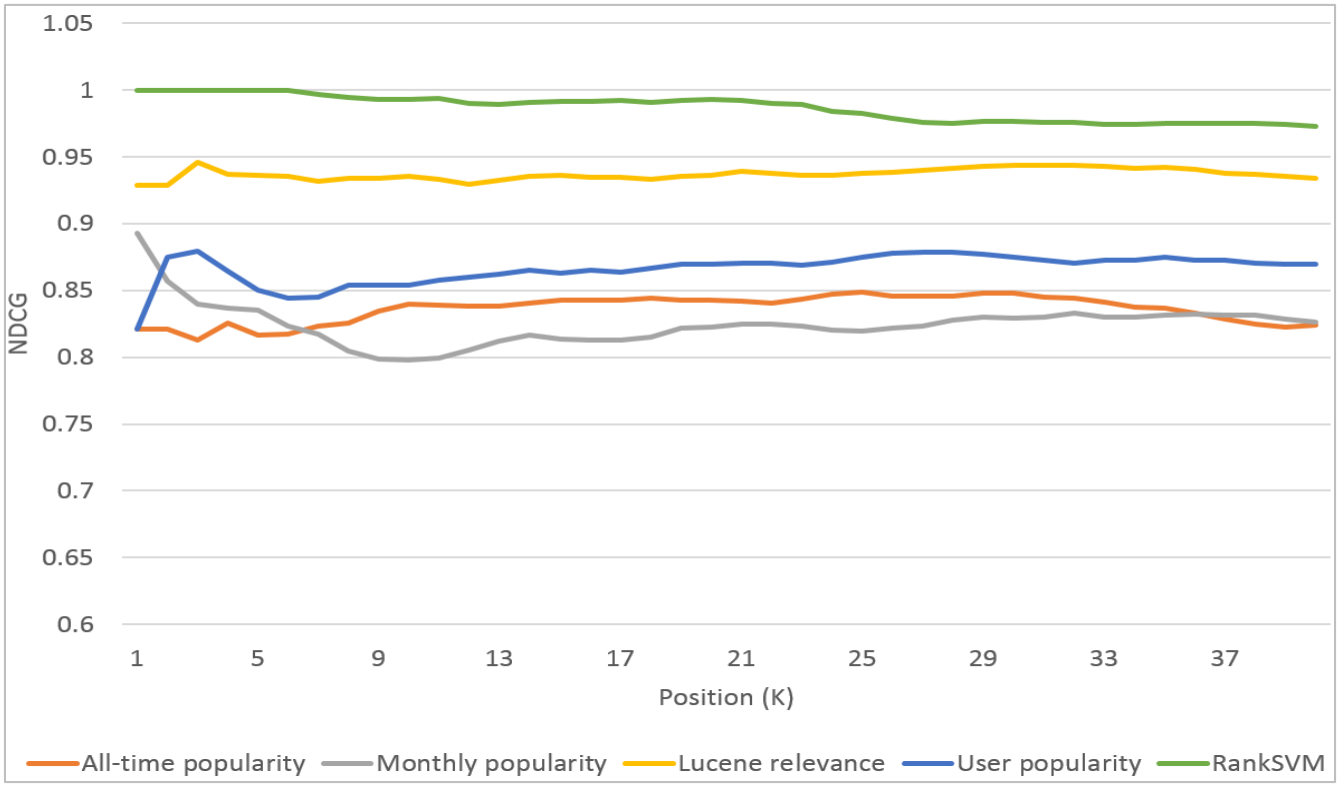
- Implemented it by ourselves with the aid of Spark MLlib

Smart Discovery of Big Geospatial Data

Ranking & Recommendation

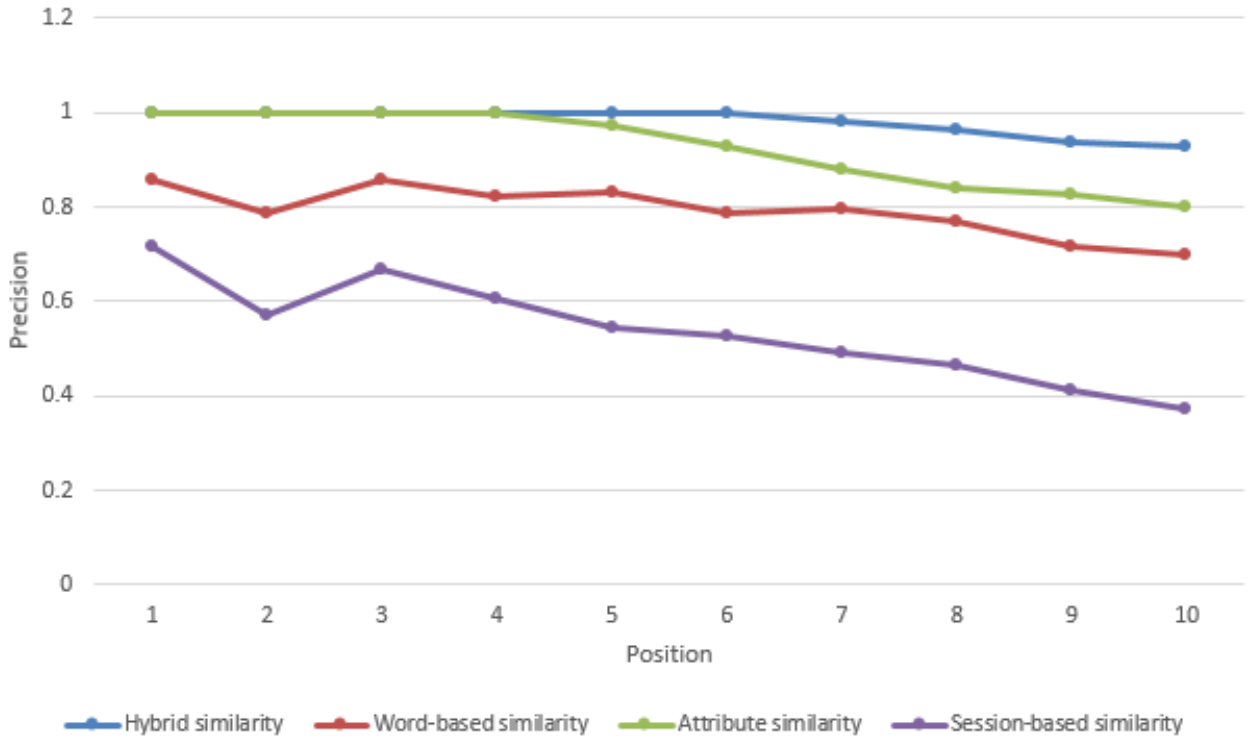
http://mudrod.jpl.nasa.gov/

NDCG (K) for five different ranking methods at varying K (1-40)



Jiang, Y., Y. Li, C. Yang, K. Liu, E. M. Armstrong, T. Huang, D. Moroni & L. J. McGibbney (2017) Towards intelligent geospatial discovery: a machine learning ranking framework. International Journal of Digital Earth (in press)

Quantitative Evaluation for Recommending Content



Hybrid similarity outperform other similarities since it integrates metadata attributes and user preference.

Y. Li, Jiang, Y., C. Yang, K. Liu, E. M. Armstrong, T. Huang, D. Moroni & L. J. McGibbney (2017) A Geospatial Data Recommender System based on Metadata and User Behaviour (in review with IJGIS)

Is it a hot research topic?

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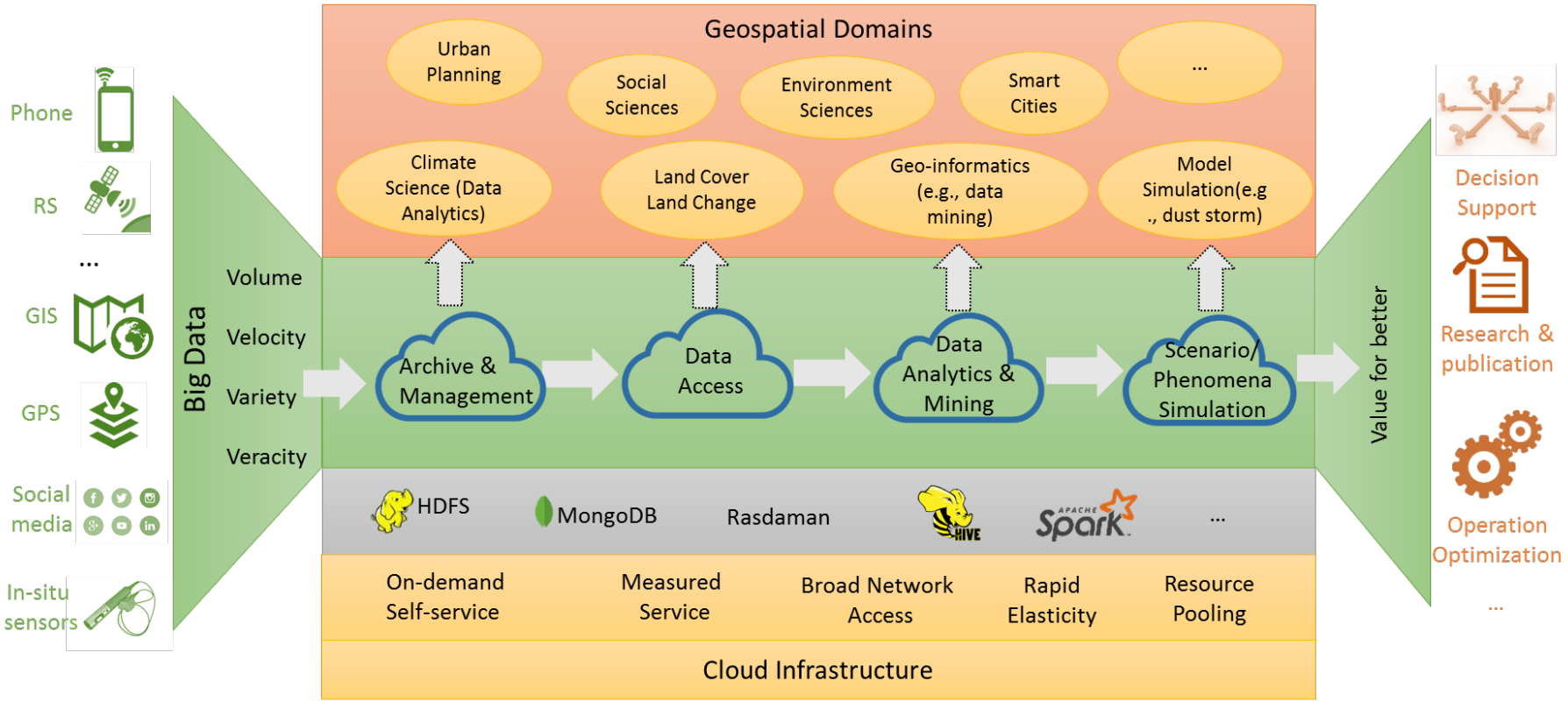
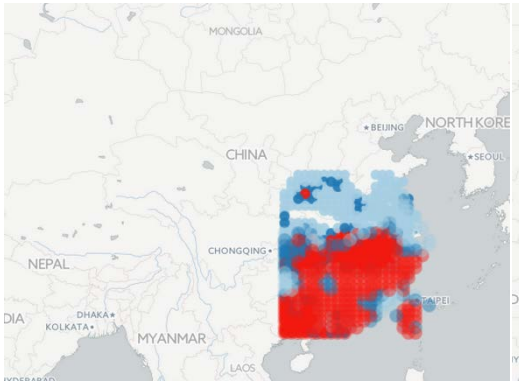
A Big Data Platform Prototype



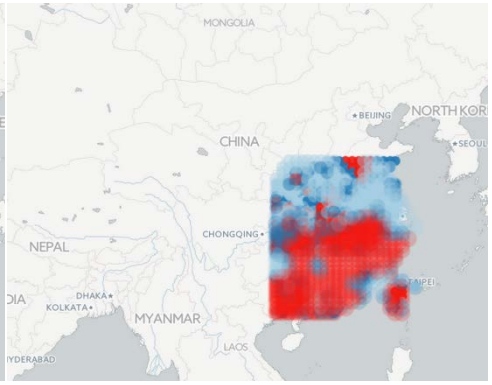
Yang, C., Yu, M., Hu, F., Jiang, Y. and Li, Y., 2017. Utilizing Cloud Computing to address big geospatial data challenges. *Computers, Environment and Urban Systems*, *61*, pp.120-128.

Detecting Anomaly Events from Big Climate Data

Time	P-value
1998/06/01	0.997109533
2008/06/01	0.992131279
2005/06/01	0.989325372
1980/08/01	0.987258529
2000/06/01	0.984524833
2011/06/01	0.98370185
2001/06/01	0.982886365
2010/06/01	0.981098687
2002/06/01	0.979622053
2008/07/01	0.978877457
2006/07/01	0.978502723

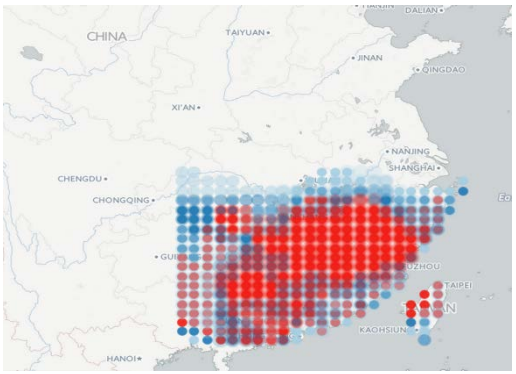


1998 June

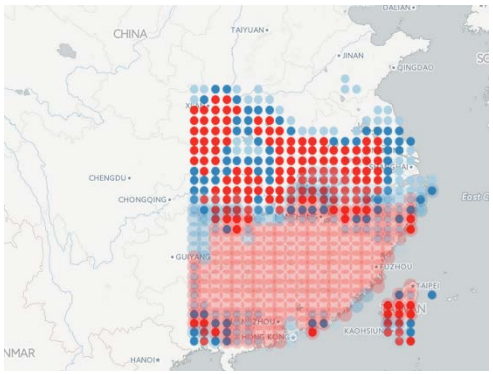


1998 July

[1998 Yangtze River floods](#)
The floods resulted in 3,704 dead, 15 million homeless



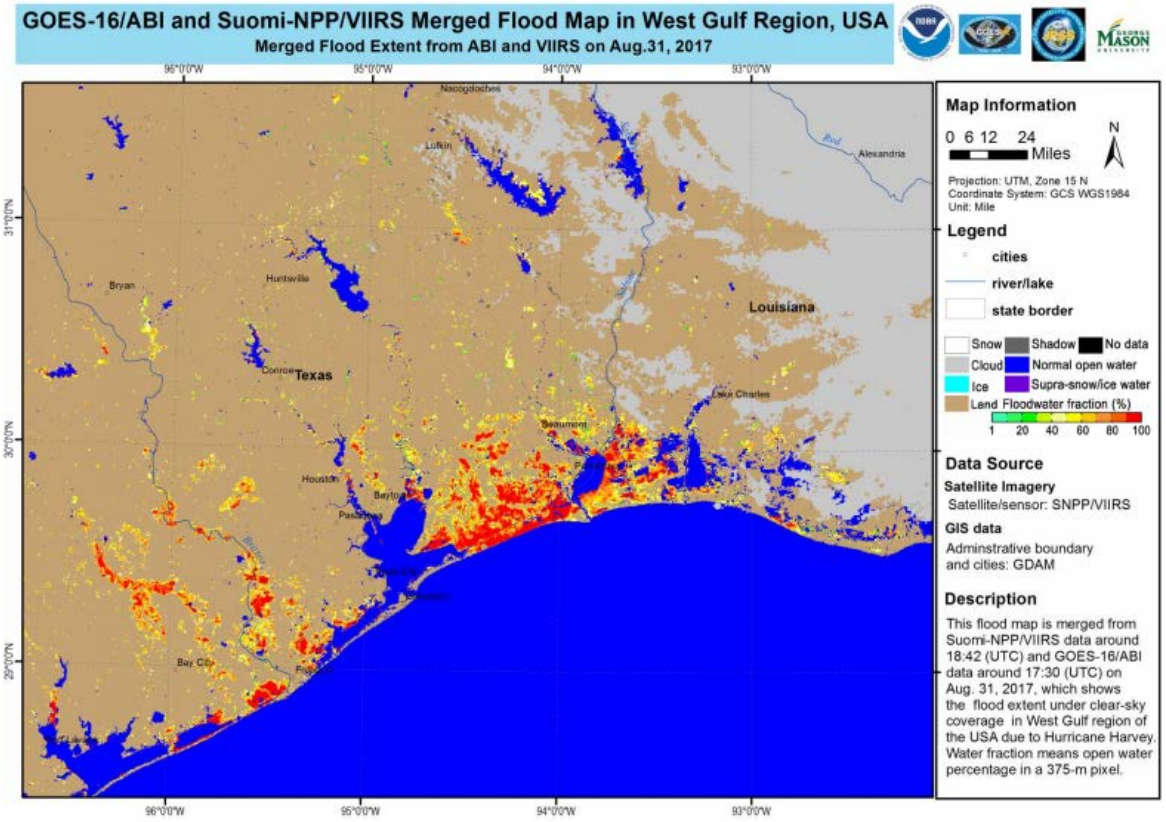
2010 May

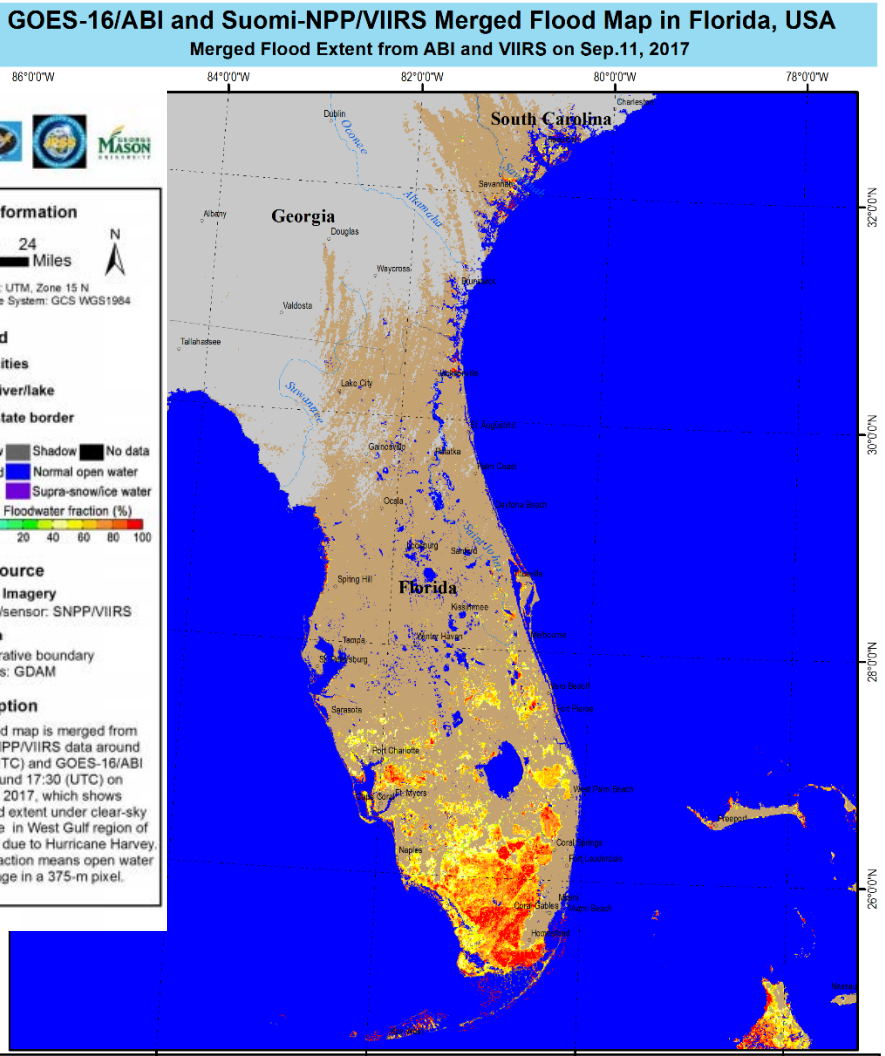


2010 June

[2010 China floods](#)
The total damages from the floods were roughly 55 billion dollars

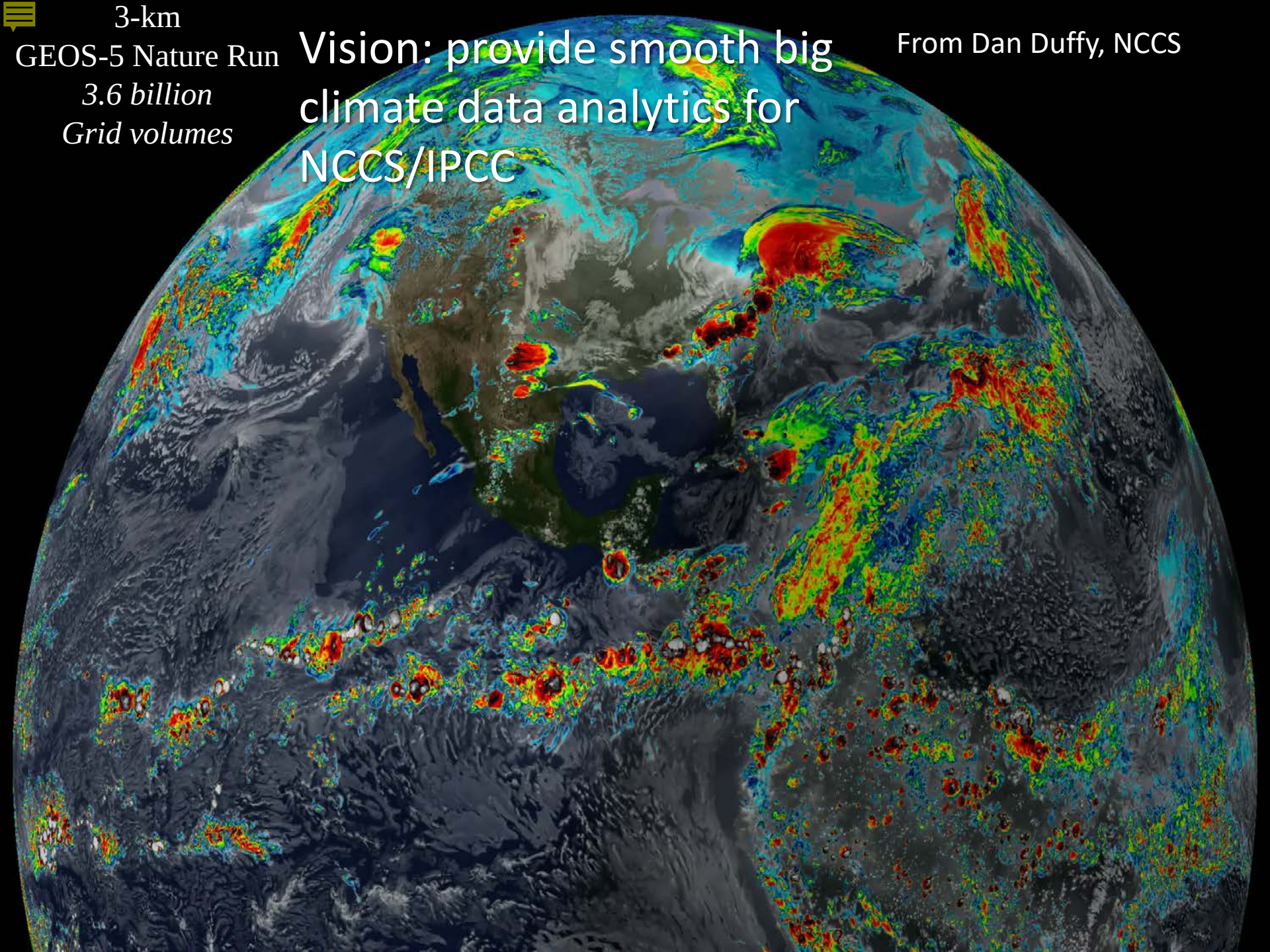
Mining flooding information continuously to save lives



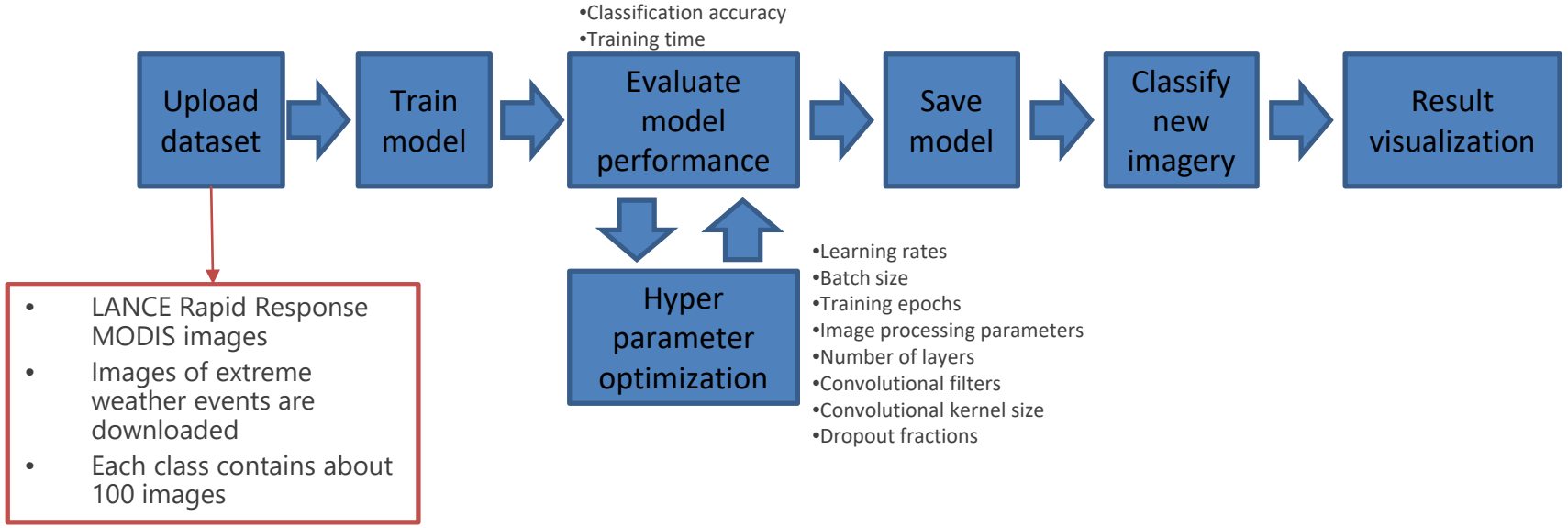


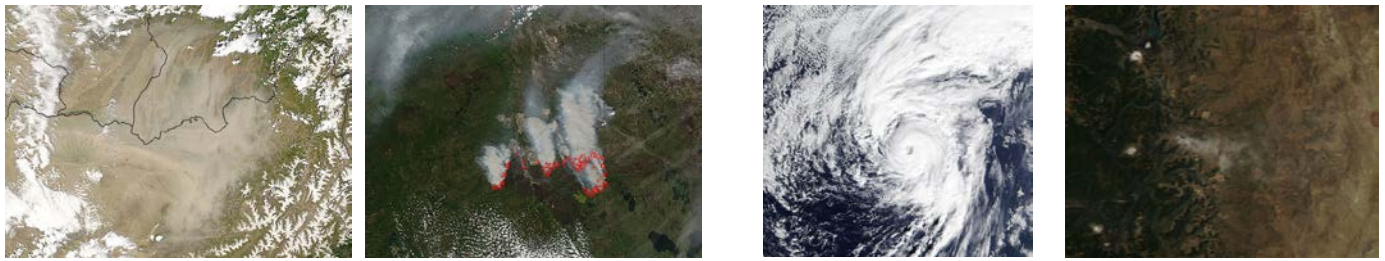
Donglian Sun

GIS Day, Purdue University, Nov. 9, 2017


3-km
GEOS-5 Nature Run
3.6 billion
Grid volumes
Vision: provide smooth big climate data analytics for NCCS/IPCC
From Dan Duffy, NCCS

Automatically learn and detect disaster events from observations





Dust Fire Hurricane Plume

Big Data and Cloud Computing: Innovation Opportunities and Challenges

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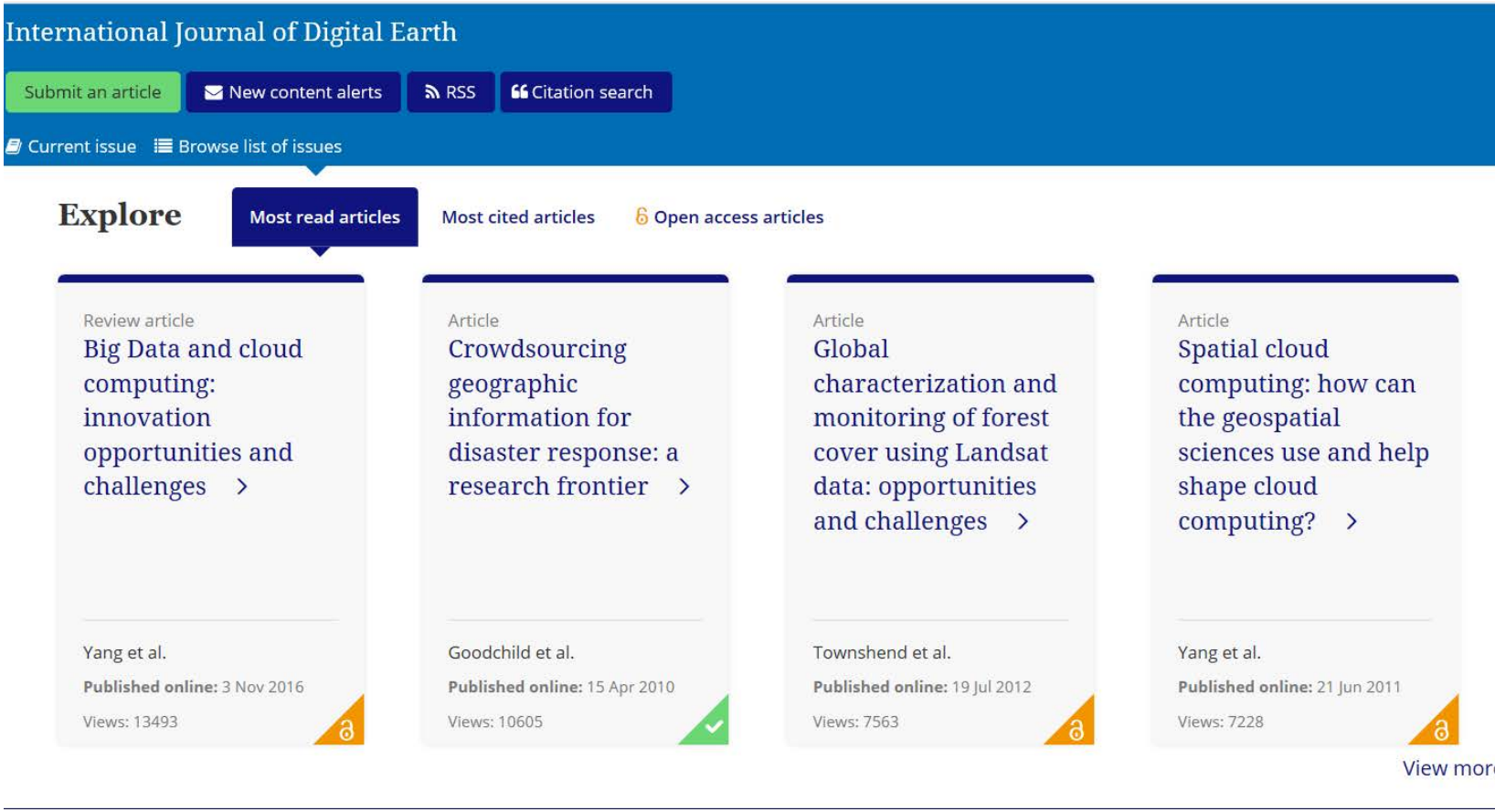
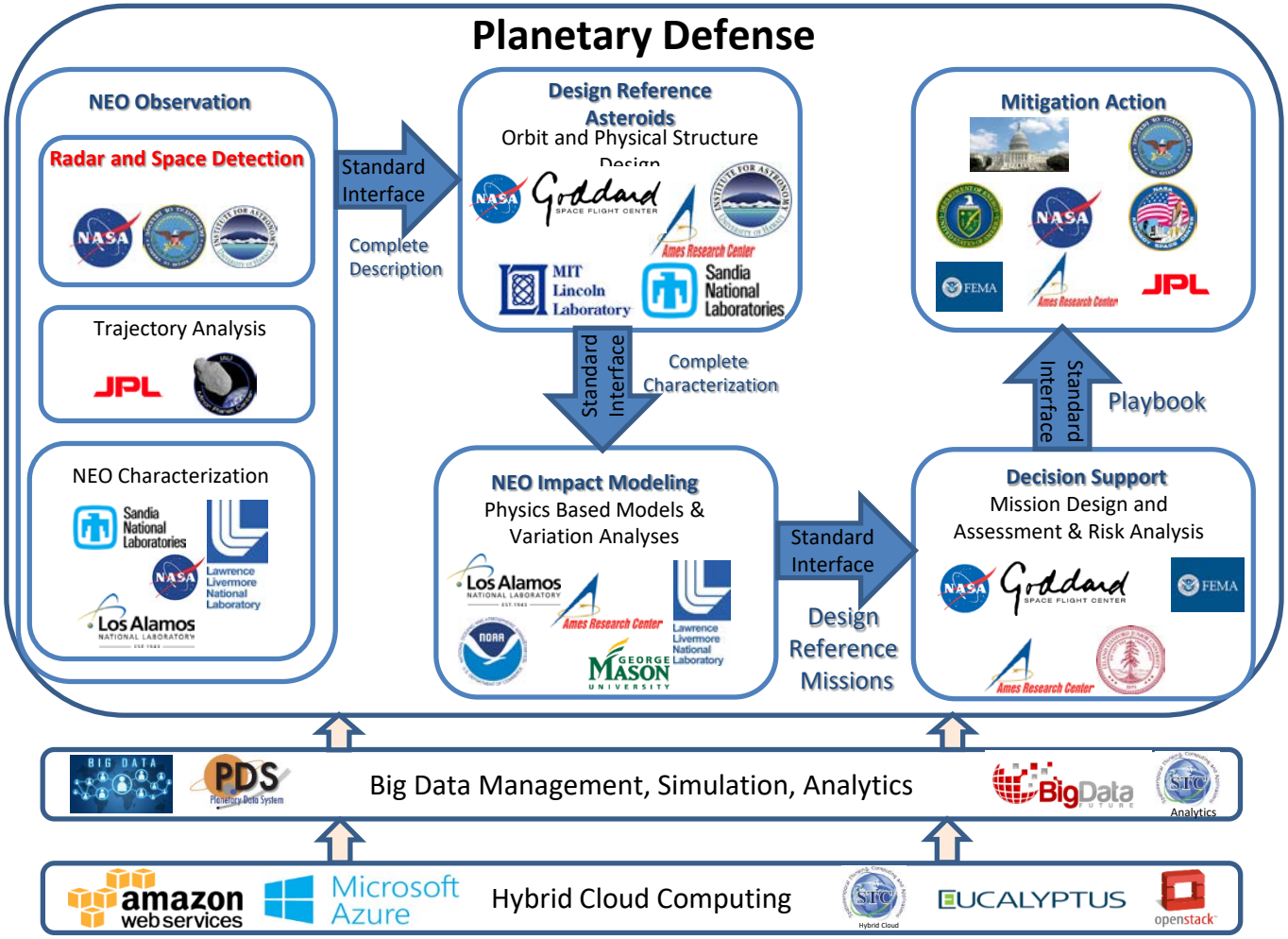
Yang, C., Huang, Q., Li, Z., Liu, K. and Hu, F., 2017. Big Data and cloud computing: innovation opportunities and challenges. International Journal of Digital Earth, 10(1), pp.13-53.



Is it cool to do research in GIS?

Discovery Channel - Large Asteroid Impact Simulation

Architectural Framework



Could I find a job?

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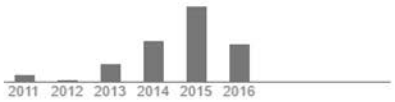
Title 1–20	Cited by	Year
Cloud computing for geosciences: deployment of GEOSS clearinghouse on Amazon's EC2 Q Huang, C Yang, D Nebert, K Liu, H Wu Proceedings of the ACM SIGSPATIAL international workshop on high performance ...	27	2010
Evaluating open-source cloud computing solutions for geosciences Q Huang, C Yang, K Liu, J Xia, C Xu, J Li, Z Gui, M Sun, Z Li Computers & Geosciences 59, 41-52	21	2013
Spatial cloud computing: a practical approach C Yang, Q Huang, Z Li, X Chen, K Liu CRC Press	19	2013
A performance, semantic and service quality-enhanced distributed search engine for improving geospatial resource discovery Z Gui, C Yang, J Xia, K Liu, C Xu, J Li, P Lostritto International Journal of Geographical Information Science 27 (6), 1109-1132	17	2013
The GEOSS clearinghouse high performance search engine K Liu, C Yang, W Li, Z Li, H Wu, A Rezgui, J Xia Geoinformatics, 2011 19th International Conference on, 1-4	13	2011
Contemporary computing technologies for processing big spatiotemporal data C Yang, M Sun, K Liu, Q Huang, Z Li, Z Gui, Y Jiang, J Xia, M Yu, C Xu, ... Space-Time Integration in Geography and GIScience, 327-351	9	2015
Building Model as a Service to support geosciences Z Li, C Yang, Q Huang, K Liu, M Sun, J Xia Computers, Environment and Urban Systems	6	2014
Optimizing an index with spatiotemporal patterns to support GEOSS Clearinghouse J Xia, C Yang, Z Gui, K Liu, Z Li International Journal of Geographical Information Science 28 (7), 1459-1481	6	2014

Citation indices	All	Since 2011
Citations	163	162
h-index	6	6
i10-index	5	5



Co-authors View all...

Zhenlong Li

Jing Li

SIGN IN

recent work on using Graphics Processing Units (GPUs) to accelerate the visualization of

How to connect with the communities?

Training

- Research Experience for Undergraduate (4-6 each year)
- Series of Training Program on State Geographic Monitoring Technology:

  Objective: provide training to Chinese executives and engineers from NASG and provisional bureaus on state geographic monitoring technology and the trend of geospatial studies in the U.S.

  – Total over 200 executives were trained in the program

Outreach Activities

- Symposiums on Spatiotemporal Thinking, Computing and Applications
  - Five years in AAG CA
  - 20 paper and panel sessions organized on average each year
  - ~800 audience in the room each year
  - Total ~ 4000 person times

Outreach Activities

- International symposium on spatiotemporal computing
  - 74 paper submissions and 34 was accepted
  - IJGIS accepted 6 papers
  - Conference proceedings:
  - 81 attendees, 5 keynotes, 53 oral presentations, and 2 panels.
  - Videos of the keynotes and panels are now available at http://stcenter.net/issc/photos_videos

What do we want to achieve?

I/UCRC for Spatiotemporal Thinking, Computing, and Application is Formed by

- **UCSB** Center for Spatial Studies (as a continuation of NCGIA) leads GIScience innovation

  -> **Spatiotemporal Thinking**

- **GMU** Center for Intelligent Spatial Computing leads computational research for geospatial issues

  -> **Spatiotemporal Computing**

- **Harvard** Center for Geographic Analyses supports applications of world significance

  -> **Spatiotemporal Applications**

Research Topics

Goal & Objectives

Advance

- Spatiotemporal thinking -> Human intelligence
- Spatiotemporal computing -> Computer software and tools
- Spatiotemporal applications -> Human capability of responding to deep scientific questions and grand engineering challenges

Collaboratively, make a difference by building the spatiotemporal infrastructure.

- Innovative Research–Academia
- Products and Services–Industry
- Operations–Agencies

How could we achieve these objectives?

In GIS

Picture from http://bensbargains.net/thecheckout/wp-content/uploads/2013/05/Pro-empire-enlist-today-he-needs-you.jpg

Thank you!

Any Question?

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