Spatial Computing Challenges in Food-Energy-Water Nexus
: A Perspective

May 24th-26th, 2016 UCGIS Symposium

Ack: NSF/CISE/IIS 1541876 (FEW: A Workshop … Data Science … INFEWS)

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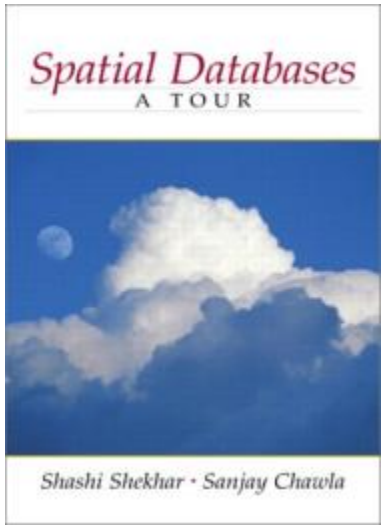
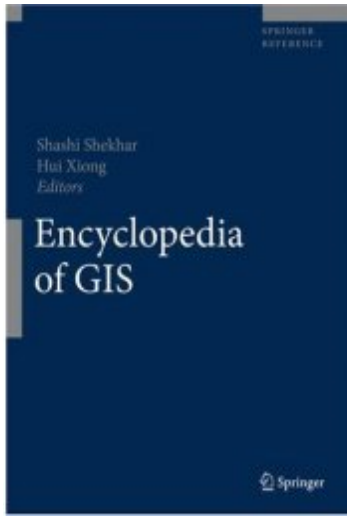
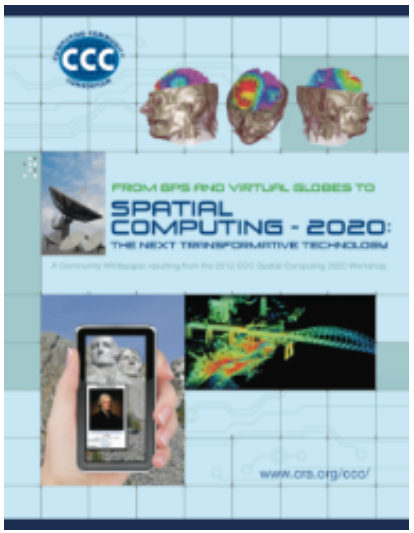
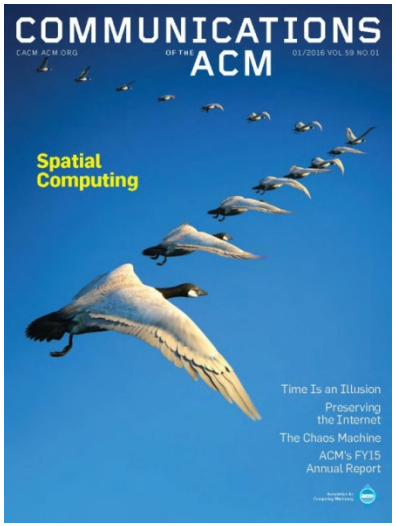








Outline

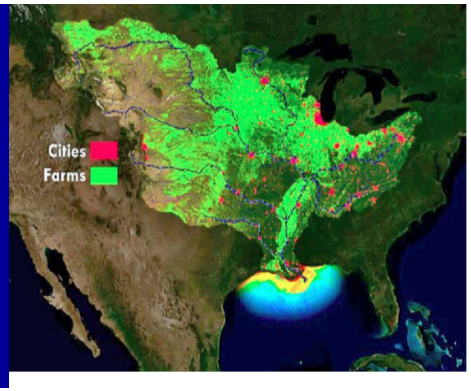
- FEW Nexus
  - Context
  - History
- Role of Spatial Computing
- Computing Challenges in FEW Nexus
- Next

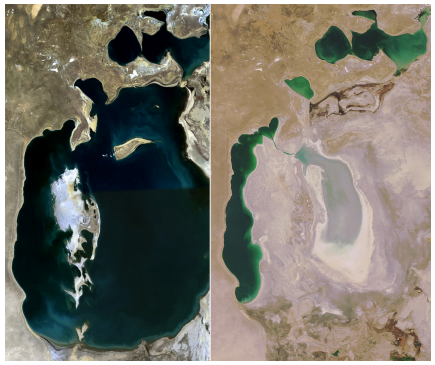
U.N. Sustainable Development Goals 2030

includes Food (2), Energy (7), Water (6), Climate Action (13), …

Downside of Piece-meal Approach

- Piece-meal policies => unanticipated problems
  - Ex. Fertilizers affect Water quality (e.g., Great Lakes, Mississippi River)
  - Ex. Bio-fuel subsidy => Rise in food prices (2008)





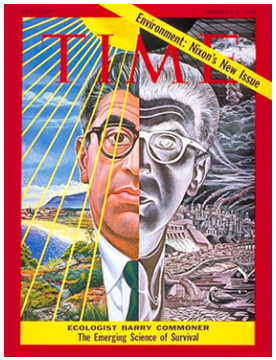
Courtesy: Wikipedia

- Crucial to understand interactions across Water, Food, Energy Systems
  - National priority
    - Reports: USDOD/NIC, NSF, USDA USDOE, USGS, …
    - Research Initiatives: NSF/USDA, USDOE
  - Global priority with initiatives from U.N. University and many countries

Alternative to Piecemeal Approach

- Holistic
  - Systems, Integrated, Networks, Ubiquitous, Context-aware
  - Ecological, Environmental, Exogeneous, Geo, Spatial, …

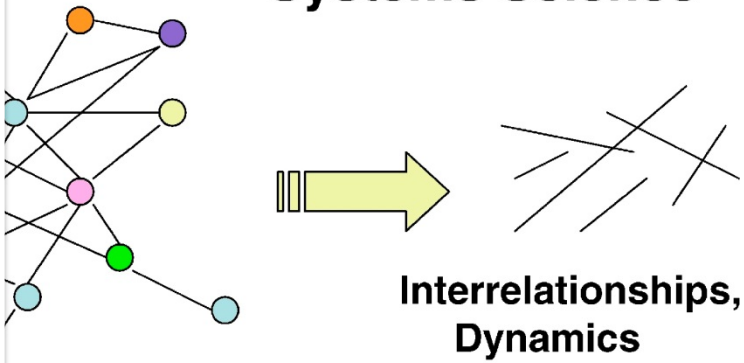
- Ex.: Ecology – Study of interactions among organisms and environment
  - Barry Commoner's laws
    - Everything is connected to everything else.
    - Everything must go somewhere.
    - Nature knows best.
    - There is no such thing as a free lunch.



- Ex.: Geography
  - Tobbler: Everything is connected to everything else but
  - but nearby things are more related than distant things

Alternatives to Piecemeal Approach

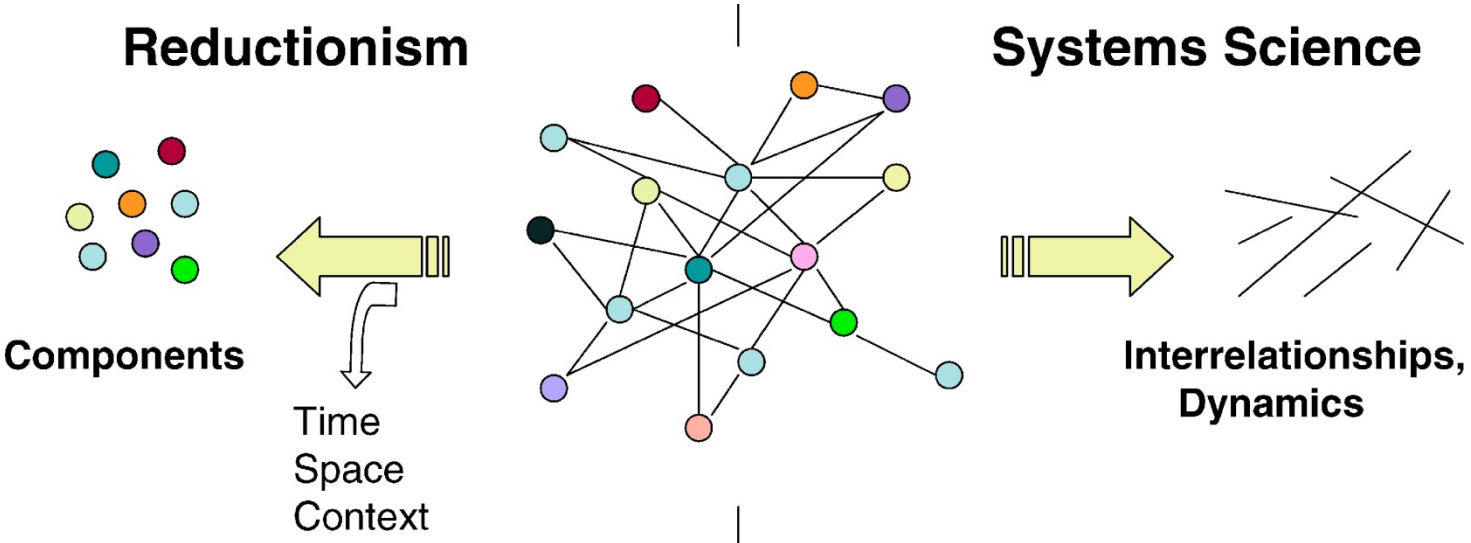
- Systems, Holistic, Integrated, Ecological, environmental traditions
  - Source: "Ahn AC et al, PLOS Medicine Open Access, July 2006"



Medical Treatments

Individualized
Multidimensional use of drugs
Time-sensitive
Space-sensitive
Synergistic

Alternatives to Piecemeal Approach



Medical Treatments

Disease-driven
Aimed for normalcy (normal range)
Additive

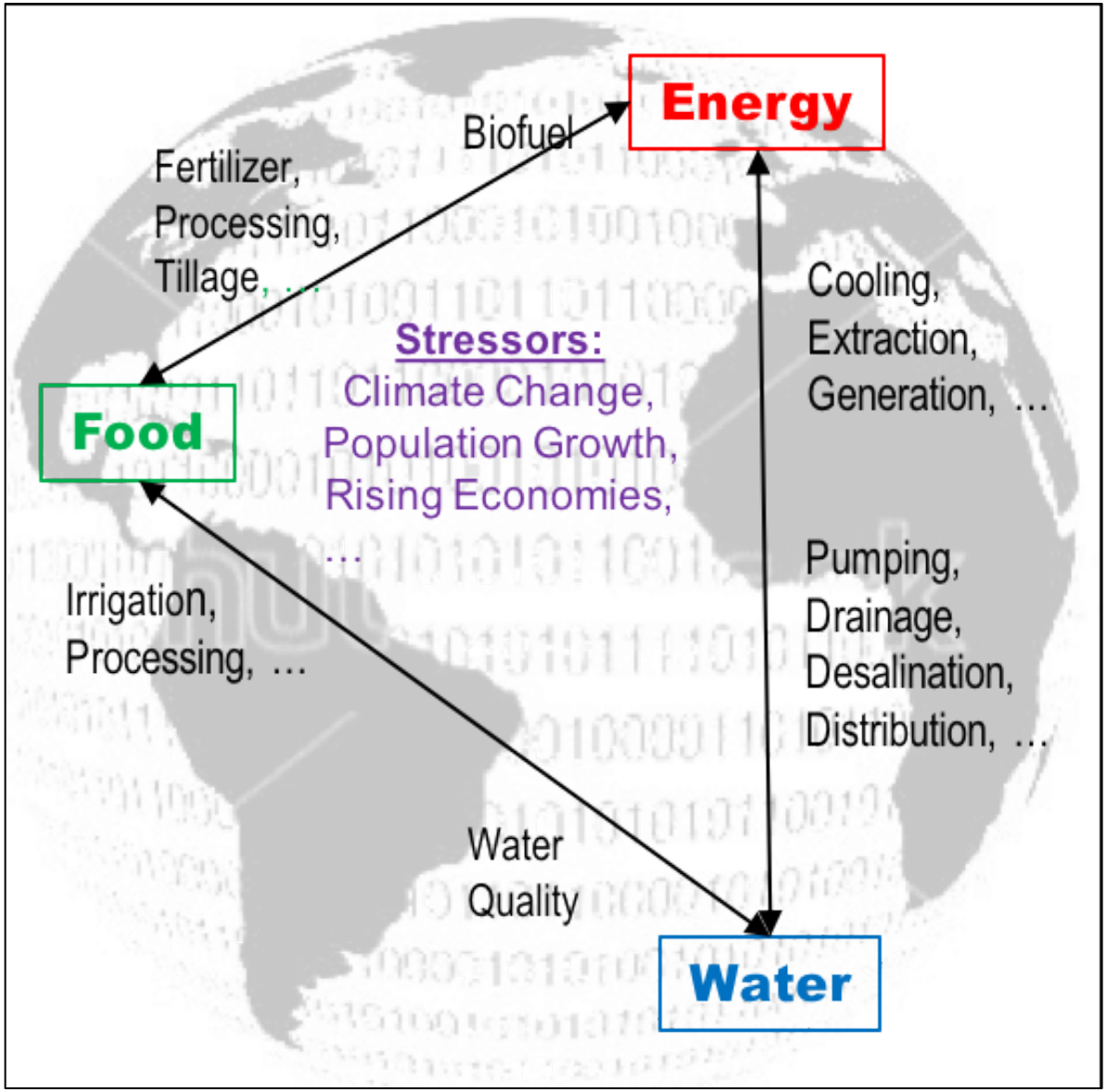
Medical Treatments

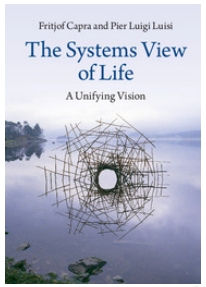
Individualized
Multidimensional use of drugs
Time-sensitive
Space-sensitive
Synergistic

Source: "Ahn AC et al, PLOS Medicine Open Access, July 2006"

Interactions among Food, Energy, Water Systems

- Piecemeal decisions in one affect the other
- **Efficiency** or abundance in one reduces scarcity in others!
- **Chokepoint:** Scarcity in one constraints growth in others!
- **Stressors:**
  - Population Growth
  - Climate Climate
  - Rising Economy





?

linear thinking
materialism, greed
UNLIMITED GROWTH ⇔ FINITE PLANET
nonlinear patterns
web of life
ecological cycles

Corporate Growth
Economic Growth
illusion
failure to include social & envir. costs
massive market failure
Population Growth
"free trade" rules
Global Capitalism
information technology
financial networks
no ethics
social inequality
social exclusion
demographic pressure
lack of family planning
illiteracy
throw-away economy
excessive consumption
waste
pollution
energy and resource intensive
Fossil Fuels
Poverty
health challenges
HIV epidemic
massive carbon release
Climate Change
Depletion of Resources
Peak Oil
increase of energy costs
floods
storms
forest fires
heat waves
droughts
declining rainfall
regional & internat. conflicts
deforestation
overfishing
overgrazing
habitat destruction
Collapsing Fisheries
Rising Temperatures
economic devastation
crop withering
impact on oil intensive industries
airlines
automobiles
industrial agriculture
polar ice
glaciers
melting of ice
rising seas
diversion of grain to biofuel
shrinking grain harvest
habitat alterations
farmers vs. cities
Water Scarcity
falling water tables
rivers running dry
lakes disappearing
Soil Erosion
advancing deserts
dust storms
degradation of land
damage to coral reefs
Species Extinction
impact on irrigation by large rivers
Threats to Food Security
Impact on Ecosystem Services
water purification
pollination
flood control, etc.
Rise of Food Prices
Climate Refugees
Famine
Failing States
food riots
chaos in world grain markets
loss of personal security
disintegration of law and order
terrorism
civil conflict
tears in the fabric of the web of life
POTENTIAL UNRAVELING OF CIVILIZATION

Figure 17.1 Interconnectedness of world problems (based on Brown, 2008).

Outline

- FEW Nexus
- Role of Spatial Computing
  - Precision Agriculture
  - Crop Monitoring
- Computing Challenges in FEW Nexus
- Next

Deconstructing Precision Agriculture

#AgInnovates2015

Wednesday, March 4, 2015
Reception | 5:00 to 7:00 pm

House Agriculture Committee Room,
1300 Longworth House Office Building,
Washington, DC

Think Moon landing.

Think Internet.

Think iPhone and Google.

Think bigger.

Come hear U.S. farmers, leading agriculture technology companies, and scientists tell how they work together to fuel U.S. innovation and the economy to solve this global challenge.

The event will exhibit three essential technologies of precision agriculture that originated from a broad spectrum of federally funded science: Guidance Systems and GPS, Data & Mapping with GIS, and Sensors & Robotics.

Moderator

Raj Khosla, Professor of Precision Agriculture at Colorado State Univ.

Farmers

David Hula, of Renwood Farms in Jamestown, Virginia

Rod Weimer, of Fagerberg Produce in Eaton, Colorado

Del Unger, of Del Unger Farms near Carlisle, Indiana

Speakers

Mark Harrington, Vice President of Trimble

Carl J. Williams, Chief of the Quantum Measurement Division at NIST

Bill Raun, Professor at Oklahoma State Univ.

Marvin Stone, Emeritus Professor at Oklahoma State Univ.

J. Alex Thomasson, Professor at Texas A&M Univ.

Dave Gebhardt, Director of Data and Technology at Land O'Lakes/WinField

Shashi Shekhar, Professor at the Univ. of Minnesota

RSVP

http://bit.ly/1CoOYoa

Hosted by the Congressional Soils Caucus

In partnership with

Agricultural Retailers Association
American Society of Plant Biologists
American Physical Society
American Society of Agronomy
Association of Equipment Manufacturers
Coalition for the Advancement of Precision Agriculture
Computing Research Association
CropLife America
Crop Science Society of America
PrecisionAg Institute
Soil Science Society of America
Task Force on American Innovation
Texas A&M AgriLife
Trimble
WinField

This is about feeding the world.

Precision Agriculture

- Reduce fertilizer run-offs, water use
- Improves yield
- Computing is critical
  - Cyber-Physical Systems
  - Data & Data Science Elements

Yield Monitors	Direct & Remote Sensing	Precision Navigation	Variable Rate Technology

Global Positioning Systems

Geographic Information Systems

Support (Farm-level) Decisions and (Insurance) Policy

CLIMATE FIELDVIEW

Seamless Field Data Collection

THE CLIMATE CORPORATION

MONSANTO

Customized Insights for Decision Making

View Field Data in Real Time

Compare Data Layers

Analyze Crop Performance in Season

Manage Nitrogen Applicatoons

Create Seeding Prescription

Monsanto, DuPont and others are pitching 'prescriptive planting' services to increase crops

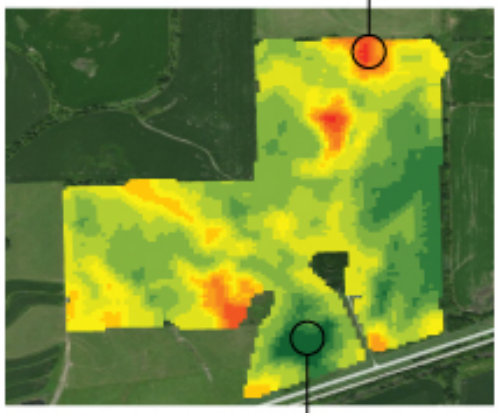
How data-driven planting services work:

1. The farmer provides field boundaries, historic crop yields, soil conditions and other data to a company.
2. The company analyzes the data and its own information about seed performance in different areas and soil types.
3. The company sends a computer file with recommendations back to the farmer, who uploads it into a planter.
4. The farmer's equipment then plants based upon the recommendations. The company monitors weather and other factors, advising farmers on how to manage crops as they grow.

Source: Monsanto

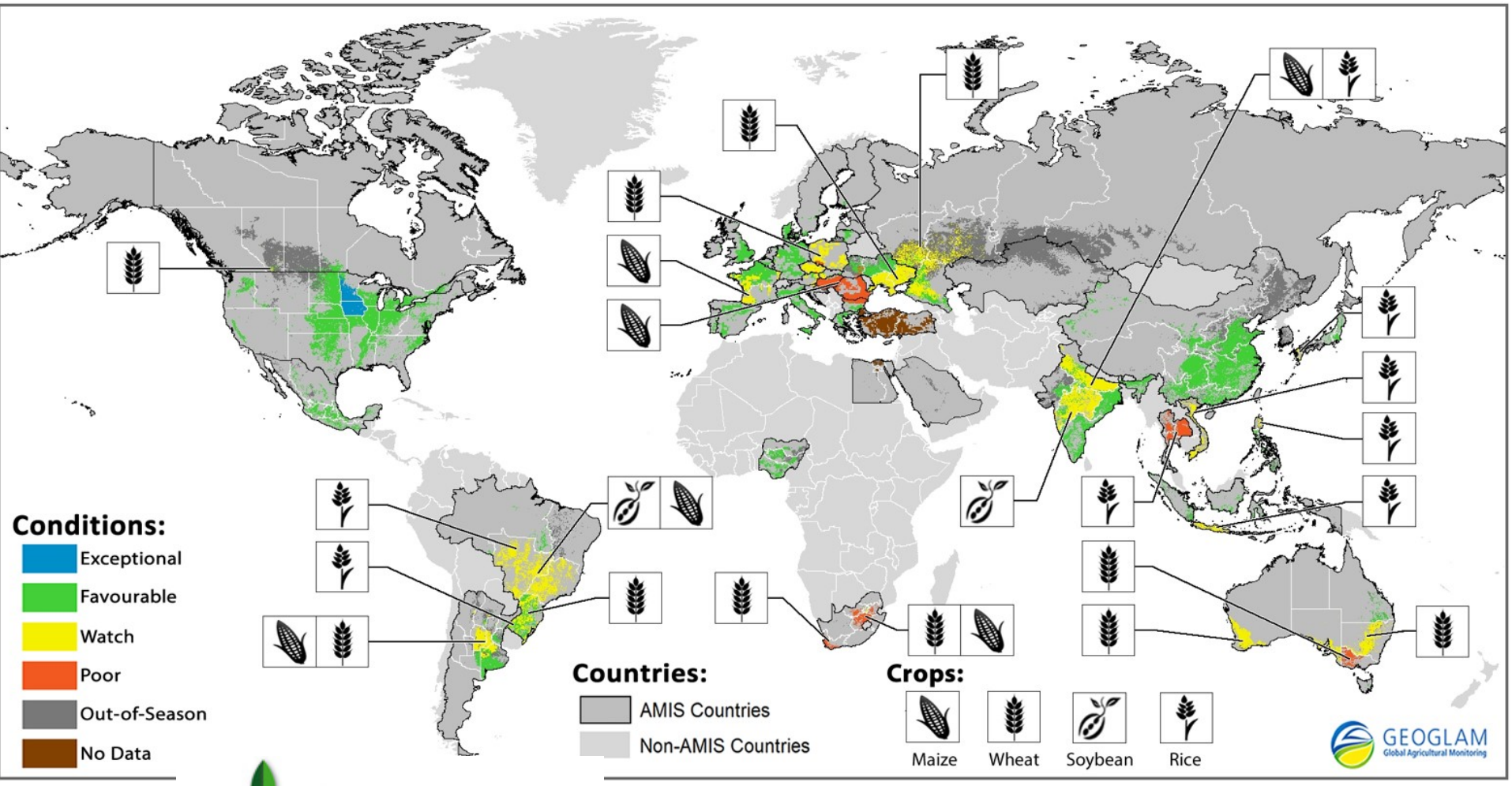
A cornfield analysis in Iowa:

Red areas: Lower number of seeds per acre recommended



Green areas: Portions of the field that can grow more corn and can take more seeds per acre

Support (Global) Decisions and Policy Making



AMIS Agricultural Market Information System

GEOGLAM Global Agricultural Monitoring

Monitor resources & trends to detect risks

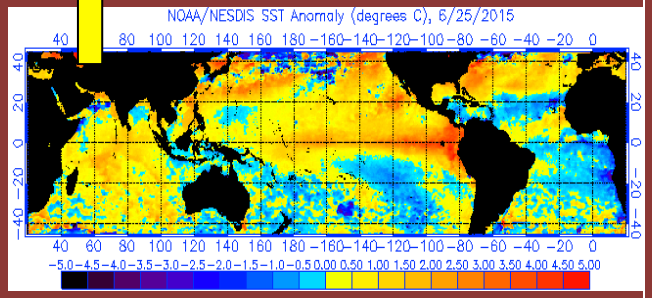
Communicate with public and stakeholders

Aral Sea Shrinkage (1978-2014)
Due to Cotton Farms

Alerts

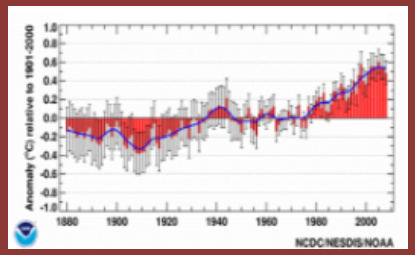
Nexus Dashboard

State

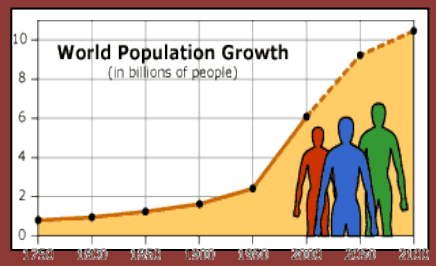


Sea-Surface Temperature Anomaly

Trends



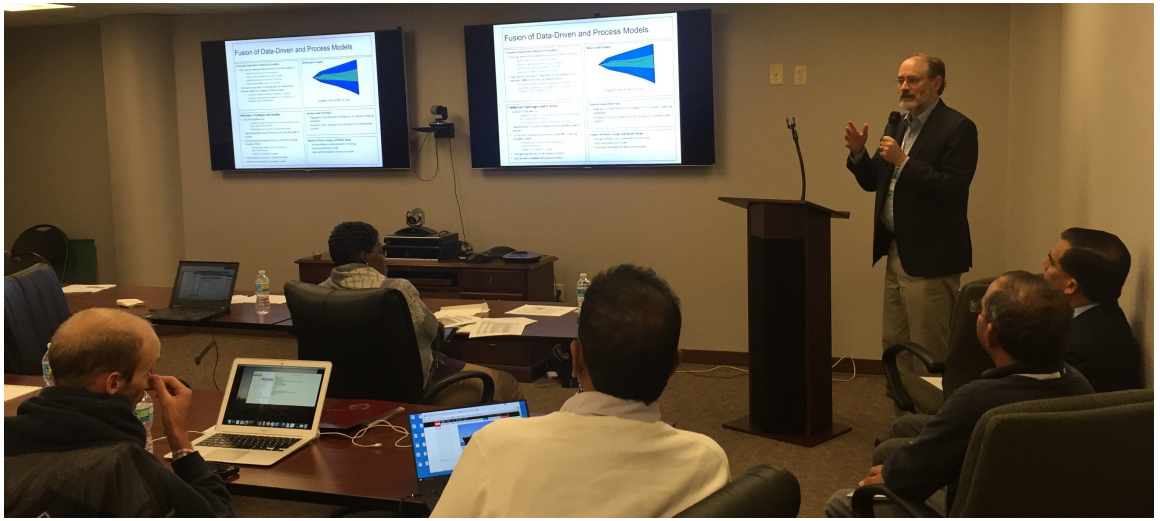
Global Temperature



Global Population

Outline

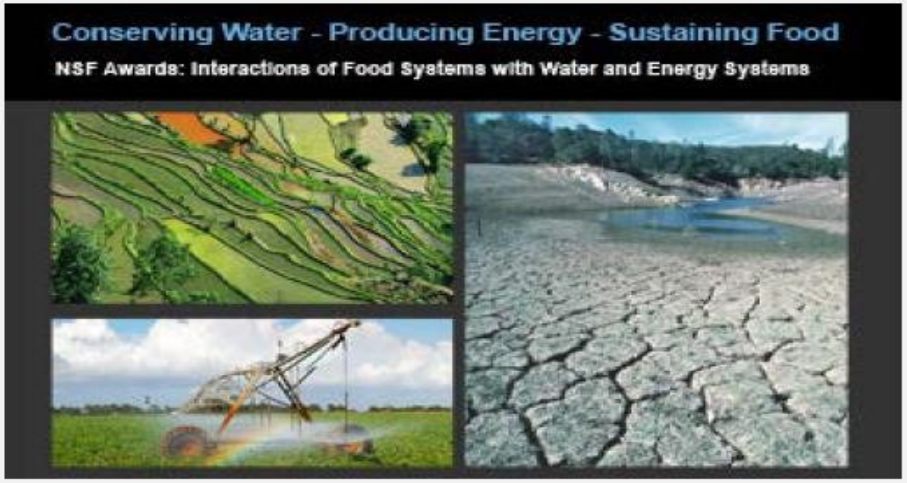
- FEW Nexus
- Role of Spatial Computing
- Spatial Computing Challenges in FEW Nexus
  - NSF INFEWS Data Science Workshop (Oct. 2015)
  - Data and Data Science Gaps
- Next



Press Release 15-090

New grants foster research on food, energy and water: a linked system

Amid population growth, drought and increased urbanization, understanding food, energy and water availability is increasingly important



How food, water and energy systems interact: a photo gallery.
Credit and Larger Version

August 14, 2015

In a world where a growing number of people lack food, water and sources of energy, providing these resources has become a challenge.

To find new answers, the National Science Foundation (NSF) has funded 17 grants, totaling $1.2 million, to support workshops on the interactions of food, energy and water, or FEW. Additionally,

- 17+ NSF Workshop grants
  - Planned across the country
  - Facilitate partnerships across disciplines, sectors
  - Define fundamental sc. & eng. research needs & questions
- Two workshop with CISE PIs
  - Technology & Information Fusion
  - Data Science

2015 Workshops

Proposal	Title	PI	PI institution	Amount	Confirmed Dates	Workshop Location
1542770	FEW NSF Workshop: Closing the Human Phosphorus Cycle	Platz	U Hawaii Hilo	$ 87,873	Jun 8 - 9, 2015	Arlington
1541880	FEW: Developing Intelligent Food, Energy,and Water Systems (DIFEWS)	Potts, Matthew D.	University of California-Berkeley	$ 49,863	Sept 28-29, 2015	UC Berkeley
1541838	FEW Workshop: "Scaling Up" Urban Agriculture to Mitigate Food-Energy-Water Impacts	Newell, Joshua	University of Michigan Ann Arbor	$ 69,242	Oct 5-7, 2015	Univeristy of Michigan, Michigan League
1541876	FEW: A Workshop to Identify Interdisciplinary Data Science Approaches and Challenges to Enhance Understanding of Interactions of Food Systems and Water Systems	Shekhar, Shashi	UMN	$ 50,000	Oct. 5-6, 2015	USDA/NIFA, Washington DC
1541883	FEW: Food-Energy-Water Nexus Workshop to Develop System Approaches and Sustainability Metrics for Evaluation	Schuster, Darlene S	American Institute of Chemical Engineers	$ 94,929	Oct. 7-9, 2015	Washington, DC
1541790	FEW: Coupling Economic Models with Agronomic, Hydrologic, and Bioenergy Models for Sustainable Food, Energy, and Water Systems	Catherine Kling	Iowa State University	$ 45,922	Oct 11-12, 2015	Iowa State University; Ames, Iowa
1541771	FEW: Food-Energy-Water infrastructure systems, engineering solutions and institutions	John L Sabo	Arizona State University	$ 94,905	Oct 13 - 15, 2015	ASU Campus
1541807	FEW: Workshop to Identify Opportunities and Challenges for Nanotechnology to Optimize and Unify Food, Energy and Water Systems	Lowry, Gregory V.	Carnegie-Mellon University	$ 58,358	Oct 19-20, 2015	Pittsburgh, PA
1541736	FEW: A sustainable rural framework workshop for the upper Great Plains.	Stone, James J	South Dakota School of Mines and Technology	$ 50,000	Oct 19 - 20, 2015	SDSM&T in Rapid City, SD
1541799	FEW Workshop - Planned Migration as a Strategy to Sustain Agricultural Production	McNider, Richard (1049050 NIFA)	University of Alabama in Huntsville	$ 56,335	Oct 21-23, 2015	NCAR, Boulder
1541866	Few Workshop: Food, Energy, and Water Nexus in Sustainable Cities	Assaf-Anid, Nada M	New York Institute of Technology	$ 98,877	Oct 20-21, 2015	Beijing, China
1541844	FEW: Conference on Environmental Change, Migration, and the Resilience of Regional Food, Water, and Energy Systems	Elena Irwin	Ohio State U	$ 97,496	Nov 4-5, 2015	Ohio State Univ.
1541868	FEW Workshop: Water- and Energy-efficient Food Production: Solutions for America's Bread Basket	Rezac, Mary E.	Kansas State University (EPSCoR)	$ 50,000	Nov 19-20, 2015	Manhattan, Kansas; Governor's Conference Nov. 18 - 19
1541642	FEW: Development and Application of Analytical Tools in Support of Food-Energy-Water Nexus Planning	Miralles-Wilhelm, Fernando R	University of Maryland College Park	$ 99,980	Oct. 27-28, 2015	Washington DC
1541890	FEW: Towards Food, Energy and Water Security in California under Changing Conditions: the Nexus Perspective	Gebremichael, Mekonnen	University of California-Los Angeles	$ 49,680	Dec 2-4, 2015	UCLA, Los Angeles, California
1541863	FEW: Technology and Information Fusion Needs to Address the Food, Energy, Water Systems (FEWS) Nexus Challenges	Ebert, David	Purdue	$ 60,105	Nov. 5-6	Napa Valley Marriott Hotel and Spa
1541694	FEW: River FEWs: Workshop to explore the nexus between food, energy and water in a large international river system	Holtgrieve, G.W.	University of Washington	$ 98,367	Dec. 10-12, 2015	U. Washington, Seattle

NSF INFEWS Data Science Workshop

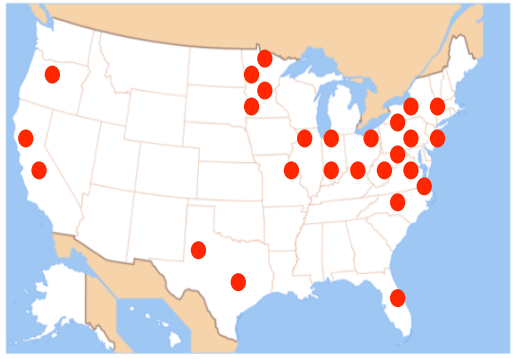
- **Goals**
  - Develop visions, Identify gaps
  - Develop a research agenda
- **At** USDA NIFA, Oct. 5th-6th, 2015
- **Co-organizers:** Shekhar, Mulla, Schmoldt
- **URL:** www.spatial.cs.umn.edu/few

- **Draft report available for comments:**
  http://www.spatial.cs.umn.edu/few/few_report_draft.pdf

- **55 Participants** (Data-driven FEW & Data Sciences)

Gov.	Aca.	Industry
26	24	5

Food	Energy	Water	DataSc.
14	10	11	20



Multi-disciplinary Multi-sectoral Participation

Data Science	Names
Data Collection, Remote Sensing	Peggy Agouris David Corman (NSF) Thomas G. Dietterich Paul Gader Raju Vatsavai
Data Exploration, Management, Dissemination	Chandra Krintz Dieter Pfoser Hanan Samet Tom Shapland (Farmlink) Goce Trajcevski
Data Extrapolation …	Chid Apte (IBM) Vasant Honavar (CCC) Zico Kolter Vipin Kumar Sanjay Ranka …

FEW	Names
Food	Parag Chitnis (USDA) Jason Hill Rattan Lal L. K. Matukumalli (USDA) Rachel Melnick Rabi Mohtar Sonny Ramaswamy (USDA) Susan Jean Riha Paul Tanger Luis Tupas (USDA)
Energy	Noel M.Bakhtian (USDOE) Robie Lewis (USDOE) Bob Vallario (USDOE) Tamara Zelikova
Water	Richard Alexander (USGS) Brad Doorn (NASA) Alan Hecht (EPA)
Cross-cutting, Social Sc., …	Inna Kouper Zachary Hayden Moira Zellner Ariela Zycherman (NSF)

Panels, Presentations & Breakouts

- **Panel:** Data-Driven FEW Nexus Science and Application Innovations
  - FEW Nexus Overview (with life-cycle analysis): Rabi Mohtar (TAMU)
  - **Energy - Water** Nexus: Bob Vallario (USDoE)
  - **FEW : A NIFA Perspective**: Sonny Ramaswamy (NIFA)
  - **Water - Food** Nexus: Rich Alexander (USGS)
  - **Energy - Food** Nexus: Louis Tupas (NIFA)
  - Drivers of FEW Nexus: Rattan Lal (OSU)

- **Panel:** Data Sci. Research Needs to Understand & Innovate for FEW Nexus
  - Data Science Challenges in **Sustainable Energy**: Zico Kolter (CMU)
  - Open-Source **Precision Agriculture** and Analytics Driven Decision Support: Chandra Krintz (UCSB)
  - **Machine Learning** Challenges: Thomas Dietterich (Oregon U)
  - **Trustworthiness** and Sustainability: Data Science for FEW Nexus in the Developing Regions: Inna Kouper (Indiana U)
  - **Informatics** Challenges: Vasant Honavar (Penn State)
  - **Remote Sensing** and Water: Brad Doorn (NASA)

Sample Domain Context Goals

- Increase efficiency and sustainability of farming
- How can consumer behavior be changed to create more sustainable FEW systems?
- Sustainability and productivity of soils
  - Restoration of degraded soils and ecosystems
- Impacts of climate change on FEW systems
- FEW strategies for mitigation and adaptation to climate change

Outcomes: F-E-W Nexus Data Gaps

- Water: Need US water census
  - Equivalent of Ag. Census and US-EIA

- Other Data Needs:
  - Energy, Food– consumption & FEW Interaction data
  - A FEW nexus data community (BD FEW Spoke)

- Data Integration Challenges
  - Varied data collection (e.g., aquifer withdrawal meter in TX & CA)
  - Heterogeneous data format (e.g., raster climate data, vector population)

Outcomes: Data Science Gaps

1. Methods to help stakeholders reach consensus on FEW issues
   - Social science methods: scenario-based discussion, design exercises, etc.
   - Computational tools: visualization, explainable/interpretable models, interactive simulation and optimization

2. Spatio-temporal modeling
   - Dealing with data collected multiple spatial, temporal scales,
   - missing values

3. Fusion of multiple model types
   - Data-driven, (causal) process-driven, economic, etc.
   - (Spatial)-context aware

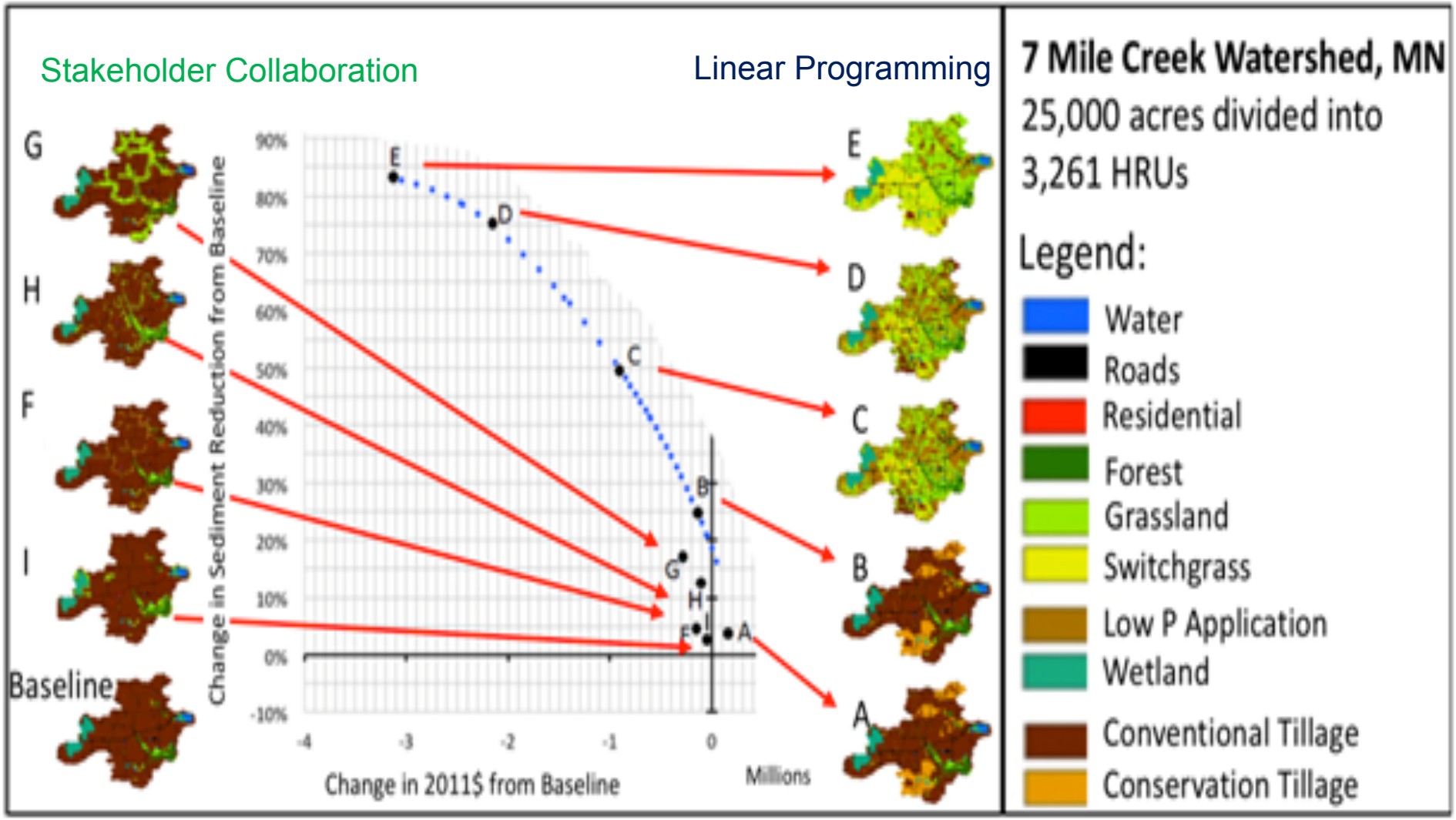
4. Lifecycle thinking for the FEW Nexus
   - modeling human behavior, understanding indirect effects of perturbations, supply chains, opportunity costs, agent-based modeling

5. Data uncertainty, incompleteness, bias
   - provenance, conflict of interest, capturing and visualizing uncertainty

Gap Example: Spatial Fragmentation in Optimization

Landscape geodesign

- stakeholder collaboration (designs F, G, H, I)
- linear programming (designs A, B, C, D, and E) – **farmers dislike spatial fragmentation**



Methodology for Guiding Stakeholders to Reach Consensus on FEW Issues

David Mulla, Moira Zellner, Ariela Zycherman, Zachary Hayden, Tamara Zelikova, Inna Kouper

Innovative Data Science Research Questions

How can data/computational science integrate existing platforms for visualization of tradeoffs and fuller implications associated with various scenarios in complex FEW systems.

Better methods are needed to represent uncertainty in meaningful ways so stakeholders can incorporate this into the decision making process.

Meaningful Graphic

Intellectual Challenges and Hurdles

Connecting small scale process modeling with coarse scale data driven models that can be used for stakeholder decision making efforts.

Representing temporal evolution of complex landscapes is challenging.

How to identify data surrogates in the absence of data?

Transformative Potential

Enabling data informed stakeholder consensus and compromise. Stakeholders make better decisions based on understanding complex FEW systems from different stakeholder perspectives.

Impact on Food, Energy, and Water Nexus

Scenario analysis and visualization could lead to significant shifts in stakeholder behavior and a more sustainable FEW system.

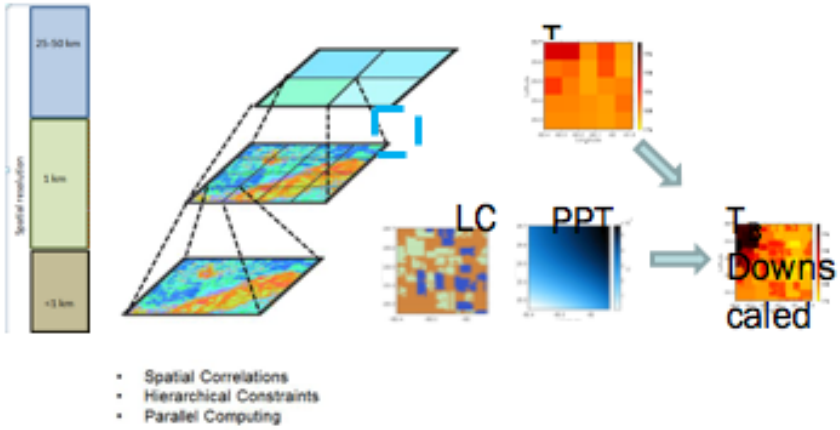
Potentially-Transformative Data-Science Challenge/Opportunity

T. Archer (NOAA), H. Samet (Maryland), S. Riha (Cornell), T. Shapland (Tule Technologies),
D.Pfoser (GMU), P. Agouris (GMU), C. Apte (IBM-Watson), S. Ranka (UFL), Brad Doorn (NASA), R. Vatsavai (NCSU)

Innovative Data Science Research Questions

1. What is the spatiotemporal grid that can effectively model multi-sensor, multi-resolution, and multimodal data?
2. How do you collect and fuse data and its provenance?
3. How do you leverage the open software ecosystem for processing big spatiotemporal data?
4. How do you find answers to complex queries such as spatiotemporal causes, events and changes?
5. How do you allow interaction of experts and stakeholders in the data collection and modeling process?

Meaningful Graphic



Intellectual Challenges and Hurdles

1. Develop techniques for leveraging spatiotemporal correlations and causations
2. Develop techniques for merging multi-resolution, multi-model data
3. Develop methods which deal with uncertainty
4. Develop big data techniques for scalable parallel and distributed processing.
5. Develop ML techniques for solving complex queries and allow expert interaction

Transformative Potential

1. Allow scientists to understand the relationships between FEW systems
2. Better understanding of impact of climate change on FEW applications
3. Participation of a wider community of stakeholders in data collection and information dissemination

Impact on Food, Energy, and Water Nexus

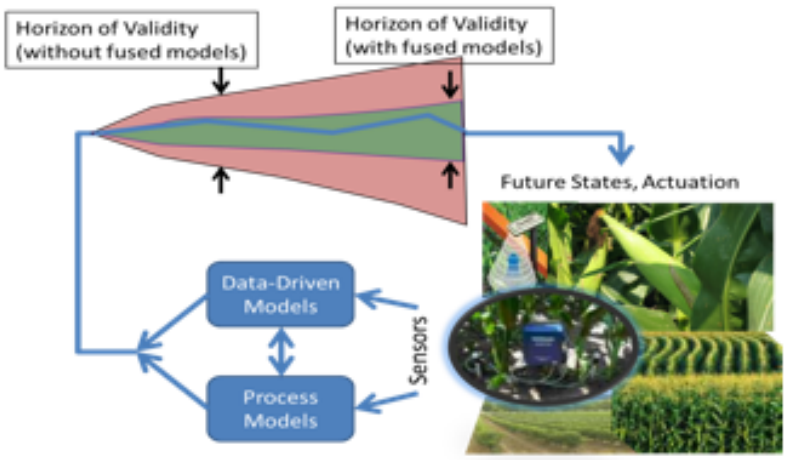
1. More environmentally rationalized use of our resources
2. Sustainability and productivity of soils
3. Empower stakeholders in the decision making processes

Fusion of Data-Driven and Process Models

Richard Alexander, Tom Dietterich, Vasant Honavar, Chandra Krintz, Paul Gador, Goce Trajcevski

Innovative Data Science Research Questions

- How can we combine data-driven and process models to
  - improve the accuracy of measurements
  - improve state estimation for process models
  - quantify and reduce uncertainty in forecasts
  - lengthen the validity horizon of forecasts
- How can we use data to characterize the relationships between different models at different scales
  - to optimize model ensembles, assemblies, couplings
  - match the spatiotemporal resolution of the models to the resolution of the FEW questions



Intellectual Challenges and Hurdles

- Lack of formalisms for
  - modeling complex measurement processes including privacy-preserving transformations
  - interfacing process models to data-driven models
- Gap between the scale of measurement and the scale of models
- Computational and approximation tradeoffs in solving coupled models
  - frequency and scale of model coupling and intercommunication
  - validity of rescaling for coupling
- Interpreting the results of coupled models
- End-to-end validation of coupled models

Transformative Potential

- Huge gains to be obtained by integration of multiple modeling paradigms
- Increased scope, accuracy, and robustness of coupled model systems

Impact on Food, Energy, and Water Nexus

- Increase efficiency and sustainability of farming
- Improve productivity of soils
- Improved risk models for insurance providers

Workshop Closing Discussion

- Discussions during the workshop brought few topics.
  - Optimization and trustworthiness under uncertainty,
    - Develop optimal decisions under uncertainty.
    - Experiment optimization in support of the FEWS-related research in chemistry (materials, fuel cells) and biology.
  - Visualization of spatial and spatiotemporal data combined with other dimensions (e.g., time, flows, etc.)
  - Develop scalable cyber infrastructure to support spatiotemporal data and scalable algorithms for various data mining tasks (pattern mining, change detection, etc.)
    - Parallelization and support of spatial data as well as streaming data.
  - Data collection, curation, and sustained support
    - Data on supply chain, trade, socio-economic state,
    - Data on food production (yield, etc.), use, and waste,
    - Data on energy production, use, and waste
    - Data on water production, use, and waste.

Outline

- F-E-W Nexus
- Role of Spatial Computing
- Computing Challenges
- Related Events
  - Dec. 2015: NSF INFEWS Solicitation
  - Jan. 2016 : NCSE
  - Mar. 2016: Midwest Big Data Hub – FEW Spoke
  - Mar. 2016: Whitehouse Water Summit
  - Aug. 2016: ACM SIGKDD Workshop on FEW
  - Dec. 2016: AGU session proposal

NSF Multi-year Cross-Directorate Initiative

News: https://foodenergywater.wordpress.com/

Research:

- Innovations for F, E, W Nexus (INFEWS)

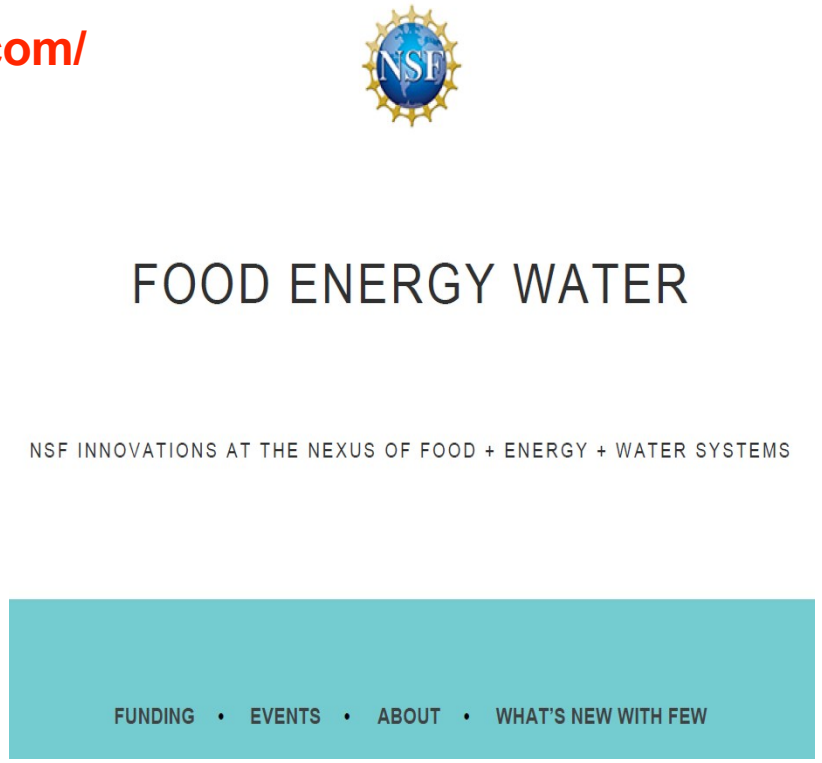
Education:

- NRT solicitation - INFEWS as a priority

Infrastructure & Community Building:

- Big Data Hub, Big Data Spoke

EPSCoR



INFEWS Data Science Workshop Draft report available for comments:
http://www.spatial.cs.umn.edu/few/few_report_draft.pdf

Innovations at the Nexus of Food, Energy and Water Systems (INFEWS)

PROGRAM SOLICITATION
NSF 16-524

National Science Foundation
Directorate for Geosciences
Directorate for Engineering
Directorate for Computer & Information Science & Engineering
Directorate for Mathematical & Physical Sciences
Directorate for Social, Behavioral & Economic Sciences
Directorate for Education & Human Resources
Office of International Science and Engineering
Office of Integrative Activities

National Institute of Food and Agriculture

Full Proposal Deadline(s) (due by 5 p.m. proposer's local time):

March 22, 2016

IMPORTANT INFORMATION AND REVISION NOTES

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised NSF Proposal & Award Policies & Procedures Guide (PAPPG) (NSF 16-1), which is effective for proposals submitted, or due, on or after January 25, 2016. Please be advised that proposers who opt to submit prior to January 25, 2016, must also follow the guidelines contained in NSF 16-1.

Anticipated Funding Amount: $50,000,000

With $9,000,000 to $15,000,000 for Track 2, Visualization and Decision Support for Cyber-Human-Physical Systems at the FEW Nexus;

INFEWS Goals

Four Tracks

1. Significantly **advance our understanding** of the food-energy-water system through quantitative and computational **modeling**, including support for relevant cyberinfrastructure;

2. Develop real-time, cyber-enabled interfaces that improve **understanding of the behavior** of FEW systems and increase **decision support** capability;

3. Enable research that will lead to **innovative** system and technological **solutions** to critical FEW problems; and

4. Grow the scientific **workforce** capable of studying and managing the FEW system, through **education** and other **professional development** opportunities.

The Food-Energy-Water Nexus

16th National Conference and Global Forum on Science, Policy and the Environment

January 19-21, 2016

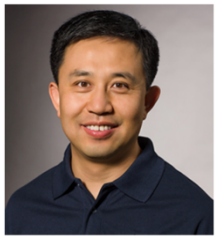
Hyatt Regency Crystal City at the Washington, DC National Airport

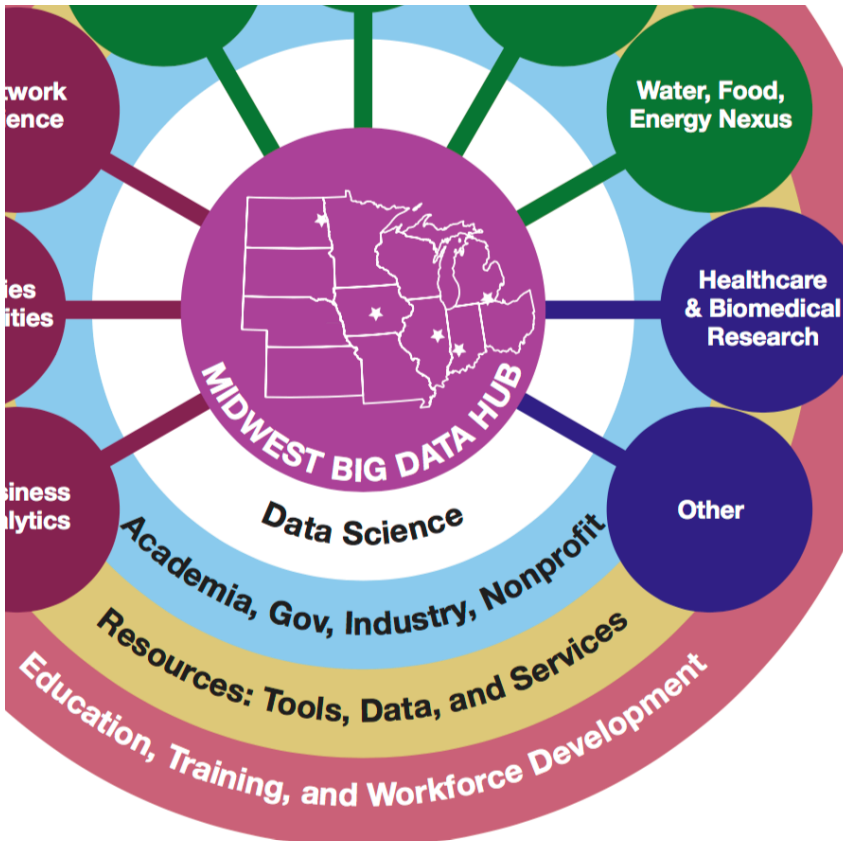
- Highlights:
  - Participation from NSF, USDA, USDOE, NOAA, USGS, NASA, USFS, etc.
  - Many sessions related to NSF INFEWS
  - Ex. S-E2: Towards a F-E-W nexus data science community

NSF Director Córdova (right) with former NSF Director Rita Colwell, who received a lifetime achievement award from National Council for Science & Environment (NCSE).

Community Building: NSF MBDH FEW Spoke







Lead: Klara Nahrstedt
Assisted by Shashi Shekhar, Shaowen Wang

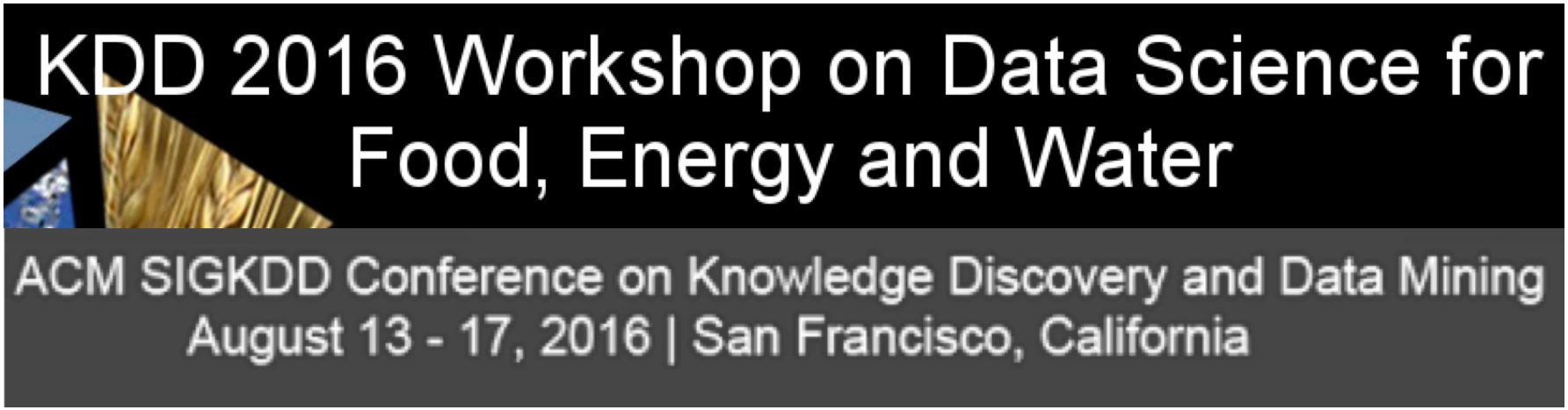
Over 40 partners

Multi-disciplinary

- Food: AgMIP/GABBS (Purdue)
- Energy: NWU Inst … Ren. Energy
- Water: Env. Eng. (UIUC, IU), Water Center at UMN & NWU,
- UMN Institute on Env., MN Population Center
- NCSA CyberGIS

Multi-sector

- Academic: TAMU, NCSU, U Glasgow, …
- Industry: IBM, Climate Corp.
- Govt.: Chicago Water Distr., NCAR, USGS, …
- NGO: Nature Conservancy
- International: U Glasgow, Govt. of Canada



Details @ https://sites.google.com/site/2016dsfew/home

NSF MBDH Travel Support for Early Career Researchers

May 27th	Paper submissions due
June 13th	Acceptance notification
July 20th	Camera-ready papers due
August 14th	Workshop date

White House Water Summit: March 22, 2016

Commitments to Action on Building a Sustainable Water Future

The New York Times MARCH 17, 2016

Water Is Broken. Data Can Fix It.