

Machine Learning - Impact on Earth Science

Earth Science Technology Forum, Panel Discussion, June 13, 2018

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AIST14 NNX15AG84G
AIST16 80NSSC17K0125
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A Research Agenda for Knowledge-Rich Intelligent Systems

Source:

Communications
of the ACM

accepted,
to appear

Knowledge Maps

- Representing scientific data and metadata
- Capturing scientific processes, hypotheses, and theories
- Interoperation of diverse types of scientific knowledge
- Automated extraction of scientific knowledge

Model-Driven Sensing

- Self-guided platforms for extreme environments
- Optimizing data collection based on modeling needs
- Adaptive sampling and automated detection of interesting events
- Crowdsourcing data collection for costly observations

Trusted Information Threads

- Integrating data from many individual investigators
 - Threading data with models, workflows, software, papers
 - Automated data analysis and scientific discovery
 - Tracking provenance and assessing trust
- Integrating data from the literature

Theory-Guided Learning

- Geoscience knowledge incorporated into machine learning algorithms
- Combining machine learning with simulation
- Modeling extreme events
- Causal discovery/inference
- Interpretive models

Integrative Workspaces

- Interactive exploration of data, models, and context
- Automated generation of targeted visualizations

Sensing in Remote Inhospitable Locations



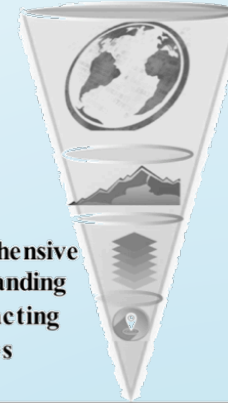
From Local to Regional to Global



High-Dimensional Multi-Scale Data



Comprehensive Understanding of Interacting Processes



Forecast sea level change in polar ice shelves

- Understand sea level rise by collecting information about feedbacks between ocean circulation and wind patterns
- Quantify rates of change with data from transition zones under the ice shelves from untethered sensors
- Rapidly analyze and detect difficult to capture events or complex patterns

Unlock deep Earth time

- Understand the signals and structural relationships that explain geophysical processes
- Trace events from early planet formation using integrated field observations of Earth processes
- Gain insight through integrating georeferenced data from different disciplines

Predict critical atmospheric and geospace events

- Characterize complex physical processes mixing turbulence, dispersion, diffusion, non-stationarity
- Provide early warning for geohazardous events like hurricanes and droughts
- Characterize uncertainty about physical system behavior

Detect ocean-land-atmosphere-ice interactions

- Identify global drivers in ocean biochemical and physical processes to understand change
- Explore couplings of separate models, phenomena, regions, events
- Synthesize wholistic models of the Earth system, e.g., carbon, climate, etc.

Motivating Geosciences Challenges

Yolanda Gil, University of Southern California
 Suzanne A Pierce, The University of Texas Austin
 Hassan Babaie, Georgia State University
 Arindam Banerjee, University of Minnesota
 Kirk Borne, George Mason University
 Gary Bust, Johns Hopkins University
 Michelle Cheatham, Wright State University
 Imme Ebert-Uphoff, Colorado State University
 Carla Gomes, Cornell University
 Mary Hill, The University of Kansas
 John Horel, University of Utah
 Leslie Hsu, Columbia University
 Jim Kinter, George Mason University
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NSF <https://is-geo.org>

Thanks!



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Acknowledgement: This material is based upon work supported by the NSF and NASA. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the NSF or NASA.