Emerging Technologies for Characterizing and Monitoring Watershed and Terrestrial Ecosystems

Executive summary

As part of the BER ESS PI meeting a breakout session was organized on the evening of Tuesday May 1, 2018 with the topic “Emerging Technologies for Characterizing and Monitoring Watershed and Terrestrial Ecosystems “.Eight different presentations on a range of different sensing technologies were given. At the conclusion of the presentations a discussion identified some common challenges and opportunities. This document provides a summary of the breakout session and the conclusions.

Breakout motivation: the essential role of sensing to support the BER Mission

The BER mission is the development of a multiscale and multidisciplinary predictive understanding of terrestrial surface and subsurface ecosystems. The approach to this is known as MODEX (Model- Experiment). MODEX requires the interplay of three components:

1. Modeling and analytics
2. Enabling technologies (e.g. databases, HPC, solvers)
3. Data collection

A large percentage of presentations and discussions at BER PI meetings focus on the first two components. While data is recognized as being essential to MODEX (and everyone wants and needs data) and multiple BER funded scientists are active in sensor or method development, repetitive data collection is by its nature not something which is seen as a core task of BER scientists.

At the same time it is recognized that to fulfil the BER vision (a predictive understanding of Earth systems at multiple space (angstrom- 1000s of km) and time (ms-decades) scales) modelers will need integrated, multi domain, multi scale datasets which are spatially and temporally dense and which are available as needed. It is also recognized that these datasets will have a multi institutional and multi discipline provenance: some data will be collected by NASA or commercial satellites, some data will be collected by the USGS, some by universities and some directly by DOE funded researchers. The BER community is aware of the emergence of novel sensors and analytical tools, novel data acquisition methods (e.g. drone based data acquisition or long term monitoring deployment of autonomous sensors) and cost reduction in both sensors and the associated enabling infrastructure (e.g. IOT associated data transmission capabilities).

The combination of the need for integrated, multi domain datasets, novel sensors and a heterogenous and distributed data acquisition infrastructure (crowd data collection) thus generates both opportunities and challenges.

On one hand novel sensing modalities allow for the low cost collection of data which could not be collected a few years ago, and on the other hand it is clear that there are often subtleties associated with the use of heterogeneously collected data sets data collection which need to be taken into account for correct data use. These developments motivated the organization of a breakout session which brought together data generators and users to talk about sensing developments, challenges and opportunities.

Breakout session talks

The session consisted of the talks listed in the table below. Each presented had roughly 8 minutes to briefly present their technology.

Airborne Geophysical Remote Sensing of the Geologic Structure of Terrestrial Landscapes	Lyndsay Ball (USGS)
UAS Hyperspectral Imaging of Terrestrial Landscapes	Shawn Serbin (BNL)
Satellite LIDAR Imaging of Terrestrial Landscapes	Maria Hunter (Universidade Federal de Mato Grosso, Cuiabá, MT, Brazil)
Quantifying Distributed Exchanges of Groundwater with the Columbia River	Michael Gooseff (University of Colorado, Boulder)
Analytical Instrumentation for in-situ Biogeochemical Research	Donald Nuzzio (Analytical Instrument Systems, Inc.)
Dissolved Oxygen Sensor System for Real-time, In-situ Monitoring of Subsurface and Aquatic Environments	Ruby Ghosh (Opti O_2, Inc.)
Exometabolomics: Revealing Biogeochemical Hotspots with Depth and by Vegetation Type in Arctic Tundra Soils	Mallory Ladd (ORNL)
Mid-infrared Spectroscopy: Determining Soil Organic Matter Composition and Decomposability across the Permafrost Region	Roser Matamala (ANL)

As shown by the titles the sensing technologies presented ranged widely in scale, underlying method and type of results. While these talks covered only a subset of possible sensing methodologies, they demonstrated the diversity of sensing tools and approaches within BER. From these talks we extracted the following sensing challenges.

Sensing challenges

The BER ecosystem can be seen as a market place where we have the demand side (the modeler/analyst/data manager), who would like integrated, multi domain datasets (above and

below ground), which are spatially and temporally dense, and which are seamlessly available where and when needed, and which cover multiple scales, and the supply side (the sensor provider/field data collector) which somehow needs to provide these datasets.

In the supply side we see a rapid development of novel and improved sensors and data acquisition platforms and substantially reduced costs (often several orders of magnitude over a multi-year period) per individual datapoint.

Several sensing challenges emerged from the presentations and discussions. Some of these were

- Many measurements are influenced by multiple physical and chemical processes, and the data needed to differentiate between processes may not always be collected as data collectors are often specialized (e.g. may only collect geochemistry or remote sensing data)
- Continuity of measurements (or even the ability to interpret measurements of different generations of sensors) with changing data acquisition platforms and methodologies is a nontrivial issue
- There are subtle differences between measurements which are taken to be equivalent. These are e.g. measurements of solar radiation, aqueous chemistry and multispectral signatures. Related to this is the issue that it is not clear whether the model predictions match the physics of these increasingly complex measurements.
- We do not have tools which tell us the most valuable parameter (or set of parameters) to measure and when and where to measure it, so we risk measuring data with a low information content
- Whereas remote sensing is happening at scale, It is not yet clear how one can cost effectively scale up point sensing
- Getting appropriate credit for data collection (especially for career scientists) is a nontrivial issue

Summary

The breakout session brought together many scientists involved in sensing both as presenters and attendees. While the sensing modalities differed by presenter many challenges were common. These challenges were identified, but not solved, but the attendees hoped that BER would be able to consider how these challenges could best be addressed as part of future BER efforts.

One of the main take-aways from this session was that just as modelers are developing integrated modeling strategies and model coupling architectures, data collectors (or their institutions) should implement an integrated sensing strategy, as such a sensing strategy is needed to deal with the increasingly crowdsourced data needed for Earth System understanding.