Title: Data for all: using satellite observations for social good

Teaser: The satellite and science communities must engage with stakeholders to identify priorities and capabilities, enabling the most beneficial use of abundant satellite sensing data.

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Satellite remote sensing offers a unique global observational platform for pursuing societal benefits in ways that are not feasible using only conventional ground-based approaches. Reaping these benefits requires an intimate engagement between the scientific community and a wide range of stakeholders. This issue has taken on a new urgency, as the strong interplay between human activity and nature drives change on almost all continents, with rules set by human activities as well as nature.

The pursuit of a more sustainable, safer, and happier future drives the study of planet Earth, with its changing environmental conditions and natural resources. Observations from visible, laser, infrared and microwave satellite sensors already provide information for managing land, water, agriculture, energy, disaster response, and ecosystem functions (*Wood et al., 2011*). During the last few decades, we have been quite successful in taking advantage of the science and observations afforded by satellites to make spectacular societal impacts.

For example, the 1976 Big Thompson Flood in Colorado killed 144, whereas the 2013 Boulder/Lyons Flood, also in Colorado, was managed with eight casualties (*Hamill, 2014*). Similarly, a cyclone off the coast of Bay of Bengal (Bangladesh) in 1991 took more than 65,000 lives and made 10 million homeless. The 2009 cyclone Aila in the same region killed a few hundred and rendered 1 million homeless (*Chowdhury et al., 1993; Paul, 2009*). A significantly improved warning system facilitated by Earth-observing satellites arguably contributed to the savings in life and property in both instances.

We are gradually developing a plethora of more mature remote sensing technology missions for routine environmental monitoring. These include Landsat and altimetry missions [AUTHOR: How is nadir altimetry different from altimetry in general? Can you provide a link to an explanatory website?], hydrologic missions like Global Precipitation Measurement, NASA's Gravity Recovery and Climate Experiment (GRACE) mission, and NASA's anticipated Surface Water and Ocean Topography (SWOT) mission. However, we lack much of the capacity required to handle the petabyte-scale influx of satellite environmental data that will become available.

An Under-Used Resource

To take advantage of satellite observational capability to enhance and accelerate societal applications around the world, scientists and other stakeholders must collaborate to find answers in the coming decade. Time is of the essence, as long gestation periods, sometimes decades, are often necessary to transition from scientific research to real-world benefits for stakeholders.

We are not yet taking complete advantage of the abundant scientific output and remote sensing data emerging rapidly from satellite missions, and we are failing to convert them to actionable products that improve decision-making for users (*Hossain, 2015*).

Thus far, the benefits have mostly accrued in the developed nations of Europe and North America. Global satellite observational coverage would be especially useful in the developing world because ground-based measurements are often largely absent here. However, programs to apply satellite observations to challenges in the developing world often struggle for longevity and continuity.

Also, the combined observational power of the multiple Earth-observing satellites too often places emphasis on the benefits from individual missions and observing systems. This observational power is currently not being harnessed to produce more durable societal benefits. The struggle for support and survival has often pitted various missions against each other. This competition ignores the synergistic power and benefits that combining data from the many Earth-observing satellites could provide, missing an opportunity to provide even more spectacular societal benefits.

A Fly's-Eye View

The scope of the opportunity and abundance of satellite observations confronting us in the not-too-distant future is already apparent. Figure 1 illustrates the basic concept behind NASA's "A-train" constellation of satellites for societal application. This series of coordinated satellites passes over the same region in quick succession, using 15 instruments to monitor various aspects of the Earth's atmosphere. The best use of the system requires a holistic use of the combined observational power of all of these satellites.

Our current and future satellite constellation essentially provides us with a "compound eye" view of the world. Like the composite eye of a fly, coordinated satellites look with many eyes at the same time to see the world from many different angles, using an array of instruments.

To take advantage of this composite view is to make better decisions, using an application that is wired to expect and accept all the different observations across multiple platforms simultaneously. Such a capability could be used to address upcoming issues in water management, for example. Figure 2 (Maswood and Hossain, 2015), illustrates how a coordinated group of satellites can be used in surface water management.

The Way Ahead

Expanding the numbers and uses of satellite remote sensing alone will not be sufficient to address society's needs. Availability of a satellite mission data portal does not necessarily imply universal access or easy applications (*Hossain, 2012*). Uncertainty in measurements, scale, end user perception, operating constraints, data latency, mission interaction, scalability, and intuitiveness of the application tool must also factor into the equation.

In anticipation of the coming era of plentiful earth observations from satellites, the earth science community must now put some thought into identifying key applications and key scientific issues. Now is the time for making connections between the regional stakeholder community from around the world and the community that provides the science that fuels an application.

These connections will allow a meaningful discussion that has been largely uncoordinated but necessary to globalize and accelerate societal applications of satellite data. The satellite and science communities must now engage with the stakeholder community to discuss what is possible and what is most urgent. These communities must set priorities to determine what must be left behind in order to scale up what is possible for the best societal applications.

Five upcoming challenges urgently need discussion, debate, and resolution as a long-term agenda:

1. What types of value-added products and information should we provide for resource-constrained public and national stakeholder communities and agencies?

2. What types of industry or private-sector partnerships will most benefit the scientific research needed to meet societal needs?

3. How can we leverage the combined observational power of our many Earth-observing satellite missions (current and future) in a synergistic manner to rapidly multiply societal applications?

4. How can we use the scientific innovation from satellite remote sensing data to trigger durable and robust applications that do not require long-term incubation or external support?

5. From an economic standpoint, what is the optimal business model to support a sustainable partnership between scientific communities and the stakeholders?

One way to answer these questions is to take a regional and thematic approach, in order to map an agenda forward for Earth science applications of satellite remote sensing. For example, a community effort in 2013 focused on conservation biology and developed highly useful recommendations that could serve as inspiration for other areas and communities *(Rose et al. 2014*). This effort brought together a group of remote sensing scientists and members of conservation organizations. They identified ten conservation questions where the use and analysis of remote sensing data would greatly increase the potential for finding and answer.

Although societal benefits from space observations share common features, what works for region X may not necessarily apply to region Y, even when the problems are similar. Thus, the need for regional solutions.

We need not confine ourselves to Earth observations from satellites. Airborne and ground-based measurement activities frequently aid in making decisions and improving applications. Also, microsatellites and unmanned aerial vehicles (UAVs) are becoming more widespread. Currently, the scientific community is divided about how these activities should be pursued in the coming years for greater benefit of stakeholders.

Because it will take time and effort to reach consensus on these many issues, now is the time to get busy and build a well-mixed environment of scientific and application stakeholder communities.

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Main image: Cyclonic Storm Aila at peak intensity before landfall in Bangladesh. Earth-observing satellites provided an early warning that saved lives and property. Credit: NASA

File: Hossain_main.jpg

Original source: http://rapidfire.sci.gsfc.nasa.gov/cgi-bin/imagery/single.cgi?image=crefl1_143.A2009145045500-2009145050000.250m.jpg

Figure 1. NASA's A-train satellite constellation creates a "compound eye" effect, providing societally useful information from many angles, using many instruments.

Figure 2. Compound eye concept of ten satellite missions working together to address surface water management application needs in South and Southeast Asia (*Maswood and Hossain, 2015).*