Priority Remote Sensing Needs for the Population-Environment Research Community

Panel contribution to the Population-Environment Research Network Cyberseminar,
"What are the remote sensing data needs of the population-environment research community?"
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"The challenge in today's practice of remote sensing for the social sciences is that it does not fall neatly into a particular set of sensor systems, does not carry one specific set of approaches, and is carried out globally in diverse systems spanning the natural-anthropogenic divide. In large part this diversity stems from the nature of social science questions to search for answers to more abstract processes that may lack a direct biophysical result (Liverman et al., 1998), necessitating indirect mapping of social processes rather than direct mapping of biophysical phenomena."

–Crews and Walsh (2009), "Remote Sensing and the Social Sciences" in the **SAGE Handbook of Remote Sensing**, p. 437 (posted on the PERN cyberseminar page)

"How do we progress from serendipity to design?"

–National Academy of Sciences (2007), **Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond**, p. 143

Social scientists, and notably population-environment researchers and practitioners[1], have made ample use of data and information[2] from sensor systems designed for other purposes (Liverman et al., 1998). In part from the social science community's demonstration of the saliency of satellite-based observation for addressing issues of societal benefit, a trend toward including social science needs[3] in mission systems design and operation is emerging in the so-called *Decadal Survey* (NAS, 2007). Yet that report's admittedly non-exhaustive list of prime examples of social applications of satellite imagery is illustrative in its "environmental" orientation: crop forecasts, geomagnetic storms and electric industry, agricultural commodities markets, deforestation economic damages, and social risks / costs of natural disasters. No one would say these categories fall outside the realm of social science, but perhaps they cluster on the less social side of the spectrum.

The point, however, of this statement is not to attack what is a generally useful report, but to use it as a jumping off point. We know social scientists have – at times quite creatively – extracted useful, accurate, and timely information from satellite imagery. What if instead we place the responsibility on the social scientists to move from the back end of the equation (as users) to the front (as participants in the design process)? This challenge was, in fact, the leading hurdle identified in the NAS report: the remote sensing

[1] The [often] different needs of researchers versus practitioners (including, perhaps, stakeholders and decision-makers) are certainly worth considering; here, however, they are considered as a single community for the sake of brevity. It should be noted however that the construction of and access to information is not necessarily equally facilitated for these groups (Latour, 1986; Robbins, 2001).

[2] The referenced NAS report uses the term "data and information" throughout, underscoring the difference in the observed versus derived. For the purposes of this discussion, the two hereafter will be considered interchangeable except where otherwise noted, in the optimistic hope that data will always lead to information.

[3] It is not suggested that "social science" needs and issues of "societal benefit" are synonymous, but (non)overlap of the two is beyond the scope of this limited discussion.

community's "inexperience" in identifying what the social science community needs / wants. The societal benefits panel on earth science applications and societal benefits, in collaboration with several other panels and working groups, did identify compelling applications for planned missions in their task of prioritizing those missions' launch dates. Should funding and gravity permit, we will have new / improved capabilities in understanding, for example, drought, soil health, and food security (HyspIRI), forest structural succession (DESDynI), areas of ozone pollution or scarcity (at different levels in the atmosphere of course, with the latter related to cataracts and skin cancer) (GEO-CAPE and GPSRO), and potential high-risk areas of vector-borne and zoonotic diseases (HyspIRI, DESDnyI, and SWOT, the first two for terrestrial systems and the third for aquatic).[4]
In all, the panel's consideration of these [relatively more] "social" science objectives (as opposed to "social science objectives") was very well done, especially given the already planned sensors, platforms, and missions (along with items social scientists are fortunate enough to rarely consider, such as inter-agency priorities and budgets, payload, and platform size). But let's push the burden more firmly onto the shoulders of the social science community: forget the planned missions, forget "traditional" band placement, and forget that cooling systems for thermal and middle infrared are heavier and more expensive. The question is simple: what do we need?

It is simple, but not easy, largely because social science applications tend to be more indirect or more "orders removed" than environmental / geologic / atmospheric / biophysical satellite-based applications. My own priorities derive from years of training, practice, and research in remote sensing, social science applications (among others), and fifteen years of fieldwork in international (and mostly developing country) settings. My personal wish list from an admittedly landscape-based perspective is as follows:

- **Continuity**
- **Pointability**
- **Visibility**
- **Simplicity**

By **continuity** I mean that new sensor systems are [readily] compatible with historical remote sensing archives. Social science questions rarely can be answered only on the basis of the last six months' data (real-time hazard assessment notwithstanding – more on that shortly). I would rather sacrifice choosing a spectral band to be placed exactly where I needed it than give up the ability to compare to Landsat archives from 1972 on (this applies to hyperspectral systems too, though would take upscaling work).

Back to the concern regarding real-time response (different from prediction), especially to hazards and disasters such as volcanic eruption, hurricane, tsunami, flooding, earthquake, armed attack, space shuttle crashes… some countries / regions have developed or are in the process of developing their own [usually lower altitude and geosynschronous] micro-satellite sensor systems for monitoring and rapid response. But a global answer negates geosynchronous observations of the entire planet at any reasonable spatial scale; yet the return time for many sensor systems can be inadequate depending where in the orbital path that platform is when the disaster occurs. Cost likely prohibits a network of satellites for this purpose (though that is one alternative), but a **pointable** system (such as SPOT) would in effect reduce return time without adding the same level of cost as a second sensor system (presumably—here I focus on social science needs and leave the feasibility studies and implementation to the engineers).

My third item, **visibility**, seems apparent. Social scientists are increasingly moving to object-based classification rather than pixel-based, or else relying upon interpretation of pattern (automated or otherwise) since many social phenomena are not necessarily spectrally distinct. For [affordable] high

[4] DESDnyI = Deformation, Ecosystem Structure, and Dynamics of Ice; HyspIRI = Hyperspectral Infrared Imager; GEO-CAPE = Geostationary Coastal and Air Pollution Events; GPSRO = Operational GPS Radio Occultation; and SWOT = Surface Water and Ocean Topography (NAS, 2007).

spatial resolution data we often use a panchromatic band that tends to be four times higher resolution than the multispectral bands onboard. While panchromatic imagery can appear quite "sharp" in densely built areas, it actually can appear relatively "muddy" in others because of the panchromatic band's placement. In many sensor systems, the panchromatic band covers portions of the visible (red) and infrared (near) spectra, effectively obscuring one of the traditionally most easily separable [landscape] areas of the spectrum. Granted, this design was likely needed to attain strong enough readings at-sensor with that smaller pixel size, but the effect is troublesome in rural and heterogeneously vegetated areas.[5]

The fourth and final item, **simplicity**, increases in importance with increasing speed as remote sensing applications become more social and more interdisciplinary. People without any formal training in remote sensing design or application expect to be able to use satellite-derived products accurately, reliably, and easily. The "fix" to this issue is more operations-based than design-based, and NASA (and USGS) has greatly facilitated the ease of use by extracting and posting web-accessible derived products that are geometrically corrected (to some degree) and by offering commonly requested data over large regions (e.g., MODIS fire data). An upgrade might involve processing regions of interest rather than using scene-based boundaries. And these agencies would still need input from users about the types of products that they would like to be able to avail themselves of "off the shelf". Recall that these products need not be derived from passive sensor systems only (consider most RADAR-derived topographic and interferometric products, such as digital elevation models or DEMs). Imagine having a standard high-spatial and –vertical resolution LIDAR-based DEM for flooding vulnerability, or a quickly produced non-bare earth DEM (i.e., including buildings) that could be quickly compared after an earthquake to the base product for rapid and synoptic estimation of damage and targeting of intervention.[6]

The above "wishlist" is not intended to be exhaustive (or agreed upon) but rather evocative. It leaves, however, three remaining key considerations:

1) there are other departments and agencies (in the US and beyond) also heavily involved in satellite development, operation, or applications. Notably the US Defense Meteorological Satellite Program's (DMSP) "Night Lights" mosaic literally shed new light on global infrastructure / development density. A proposed NightSat with improved spatial resolution (50m) could greatly assist in assessing levels of development as well as understanding widespread outages associated with hazards and disasters.[7]

2) Social scientists and the *Decadal Survey* report recognize the need for integrating field data, and population-environment researchers have led the social science community in implementing and integrating socio-economic and demographic surveys with remotely sensed data, both methodologically and theoretically (Liverman, 1998). Perhaps it is time to consider more novel data streams? Social media have been recently used with internationally recognized success in monitoring disease outbreaks. Dr. John Brownstein, a physician at Children's Hospital Boston (CHB), collaborated with fellow CHB computer scientist Clark Friefeld to innovatively employ Twitter health-related posts that could be mapped (freely) on Google Earth (see a report at http://news.discovery.com/human/swine-flu-google-maps.html). His team's approach was so successful that CDC (US Centers for Disease Control) now has multiple active

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[5] Thanks to Gordon Wells and Teresa Howard of the Center for Space Research at the University of Texas for a conversation years ago that clarified this then-emergent issue.
[6] LIST (LIDAR Surface Topography) would generate 5m spatial resolution data with roughly decimeter vertical accuracy, and was put in the 2016-2020 priority category for launch.
[7] The proposed spectral placement at one point prioritized continuity with older [non-satellite-based] observations and equations, and unfortunately mapped onto spectrally overlapping areas for many typical landscape signatures, including those needed to separate types and intensities of urban lighting. My above reticent comment of course is in exact contradiction to my earlier statement that continuity is more important than band placement, illustrative of how difficult it is for NASA et al. to design sensor systems that will please all people at all times for all applications.

“mons” (monitors) for contagious diseases including H1N1 swine flu (http://www.cdc.gov/socialmedia). But the use of social media, some of which may be geolocated, (re)raises ethical questions the population-environment community has pioneered in addressing: privacy and confidentiality (see especially VanWey et al., 2005). What guidelines can this community develop to weigh and establish the costs and benefits to individual’s personal information, and how are issues of informed consent resolved?

3) Lastly, there remains a huge divide between developing/rural and developed areas/populations in terms of access. Nowhere in the NAS 2007 report section on ensuring access are the issues of [reliable] electricity, [fast] internet, and [language-dependent] literacy mentioned, a reminder that even our most sophisticated and critical social science or remote sensing needs in many ways come down to an issue of development.

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