Gap Analysis of Land Topography Data Derived from Satellite Imagery for Project Good Earth

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Abstract:

The implementation of Center for Advancement of Science in Space (CASIS)'s Project Good Earth requires a gap analysis of the current use of remote sensing instrumentation for humanitarian applications, such as natural disaster hazard identification and management as well as disaster relief and recovery. A synthesized list of current and planned satellite-based remote sensing instruments capable of producing land topographic datasets has been developed. The list highlights the instruments' applicability to humanitarian mass movement analysis and the individual assets and shortcomings of each instrument. Mass movements are colossally destructive, gravity driven, currents of geologic material such as landslides, lahars, etc. Existing mass movement model accuracy is restricted by the availability and spatial resolution of digital elevation models (DEMs). By testing the best available satellite-derived DEM in a realistic hazard assessment scenario and comparing the results against a 1 meter airborne Light Detection and Ranging (LiDAR)-derived DEM, the accuracy of the satellite data can be assessed against an ideal DEM for mapping a potential large-scale mass movement event. The utilization of land topography data for mass movement hazards identification, management, and response, is one part of the overall project which will aid CASIS proposal analysis boards in deciding which remote sensing innovations to support on the International Space Station in order to best serve humanity.

Background:

Mass movement events occur when geologic material becomes mobilized. Driven by gravity, these events are extremely destructive and very difficult to predict.

- When a destabilizing event, such as an earthquake or volcanic eruption, occurs large sections of the ground surface can become mobilized then channelized to the area of lowest potential energy.
- Large-scale mass movement hazards include avalanches, lahars, landslides, lava flows, and mudflows. These are often rapidly occurring, high-energy events that threaten human lives and developments.
- With over 160 magnitude 6 or greater earthquakes in 2004 alone, and an average of 60 volcanic eruptions per year, major mass movement events are inevitable and must monitored before a catastrophic event occurs to prevent loss of life and resources.[7]

Accurate and up to date topographic information is necessary to monitor the changing dynamics of the Earth. Topographic data sets are ground elevation maps relative to mean annual sea level. DEM are used in conjunction with other datasets to identify areas of low ground stability, and the area of lowest potential energy where the ground mass is likely to become channelized.

Topographic data is used:

- During disaster responses to identify regions where damage was the most severe, guiding the planning and distribution of aid.[1]
- To plan for potential mass movement events and create hazard maps of areas at risk. When combined with geologic data and hydrological data, the conditions that trigger a mass movement can be identified before a probable event occurs and the areas at greatest risk can be evacuated.[3]

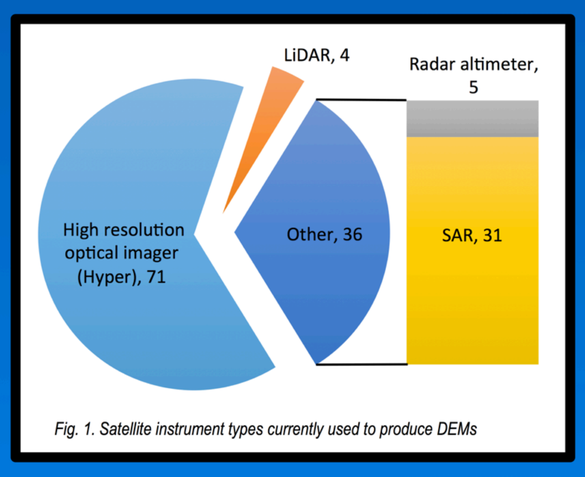

Fig. 1. Satellite instrument types currently used to produce DEMs

Works Referenced:

1 Hodgson, M. E., Battersby, S. E., Liu, S., and Sulewski, L., *Geospatial and Remote Sensing Data Use By States and Counties in Disaster Response and Recovery: A Nationwide Survey*, Columbia, SC: 2013.

2 International Charter on on Space and Major Disasters, "International Charter Space and Major Disasters: Implementing Universal Access," 2014.

3 Schilling, S. P., *Laharz_py: GIS Tools for Automated Mapping of Lahar Inundation Hazard Zones*, Reston, VA: 2014.

4 U.S. Geological Survey, "Shuttle Radar Topography Mission Statistics," *U.S. Department of the Interior* Available: http://srtm.usgs.gov/Mission/quickfacts.php.

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7 Simkin, T., Tilling, R. I., Vogt, P. R., Kirby, S. H., Kimberly, P., and Stewart, D. B., This Dynamic Planet: World Map of Volcanoes, Earthquakes, Impact Craters, and Plate Tectonics, 2006.

8 Center for Advancement of Science in Space, Annual Report, 2014.

Who is CASIS?

NASA is partnering with the **Center for Advancement of Science in Space** (CASIS) and the United Nations Institute for Training and Research (UNITAR) and UNITAR's Operational Satellite Applications Program (UNOSAT) to support the utilization of satellite generated datasets on the state of the earth that can be utilized for the betterment of people on earth. CASIS, a nonprofit agency founded in 2011, was charged by the US congress with the management of the International Space Station (ISS) National Lab.

Project Good Earth (PGE) was created to expand the use of the ISS for imaging Earth from low earth orbit by supporting projects that could substantively increase the quality of life on earth in both the developed and developing nations.[8]

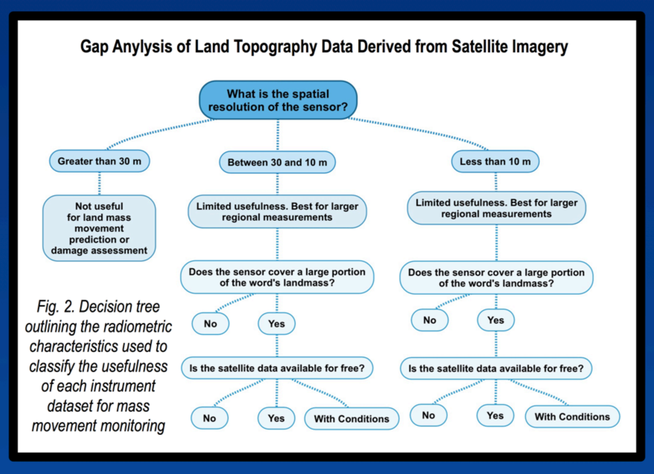


Fig. 2. Decision tree outlining the radiometric characteristics used to classify the usefulness of each instrument dataset for mass movement monitoring

Methodology:

A list of instruments already identified as being capable of producing land topographic datasets from the World Meteorological Organization's Observing Systems Capability Analysis and Review Tool (OSCAR),[5] to produce a synthesized list of current and planned satellite-and planned satellite-based remote sensing instruments, detailing the instrument type, spatial resolution, coverage period, operational dates, and data access rights of each instrument:

- An instrument was classified as "good" only if it had a spatial resolution of less than 10 meters, if it was free to humanitarian groups without any conditions, and if it was still in operation.
- An instrument was classified as "acceptable in some scenario" if it had a spatial resolution between 10 and 30 m and it was free to humanitarian groups without any conditions.
- An instrument was classified as "bad" if it had a spatial resolution of greater then 30 meters and/ or was not free under any conditions, or if the coverage period did not allow for yearly repeat coverage of most of the Earth's land surface.
- Instruments that were free to humanitarian groups with conditions, such as the data sets available through the International Charter on Space and Major Disasters, were classified as "bad" because the charter restricts data access to after a disaster has already occurred. Mass movement monitoring using DEMs is an important part of preventative hazard assessments, and the data loses its value after the disaster has already occurred.

The best available satellite derived topographic data was then processes in a realistic mass movement model and compared to a spatially ideal dataset used by the U. S. Geologic Survey (USGS).[3]

Humanitarian and Space Policies:

Established in 2000 by 23 space remote sensing agencies, the International Charter on Space and Major Disasters was designed to "promote cooperation between space agencies and space system operators in the use of space facilities as a contribution to the management of crises arising from natural or technological disasters".[2] Pre-certified national disaster management authorities can invoke the charter after a disaster has occurred, in order to have free access to high-quality remote-sensing images during the response and recovery period of a disaster.[2,6]

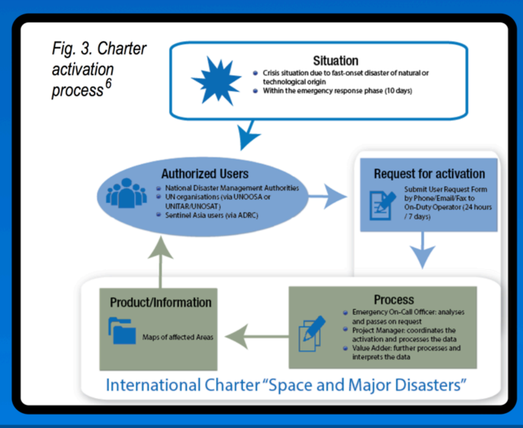


Fig. 3. Charter activation process[6]

Reactionary phase humanitarian remote-sensing damage assessments are used strategically to allocate resources the areas of the greatest impact after a natural disaster has already occurred. Visible light and false color two-dimensional remote sensing products have been found to be the most important after a disaster has already occurred, because of the blatant scars on the landscape such events produce.[1]

Topographic data is most important before a disaster has occurred. Preventative hazard assessments, such as what can be done with high-quality topographic data for predicting and monitoring mass movements, aim at mitigating potential losses through public education and evacuation strategies. They are used to quantify that a disaster is going to occur and/or predict the most plausible damage scenario. Data is not available through the international charter for preventative hazard remote sensing.[1,2,6]

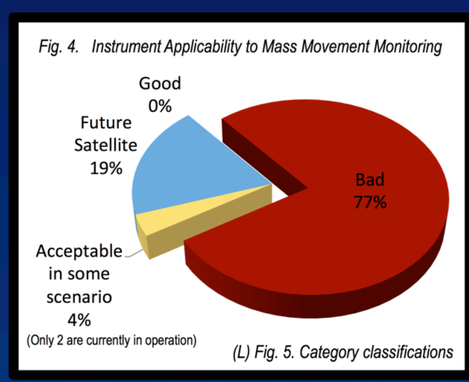
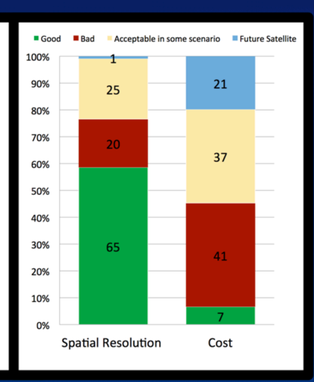


Fig. 4. Instrument Applicability to Mass Movement Monitoring



(L) Fig. 5. Category classifications

Results:

None of the 111 satellite instruments analyzed met all of the requirements to be categorized as "good" for critical mass movement monitoring by humanitarian aid groups:

- 4 instruments were available for free, but offered a spatial resolution between 10-30 meters; NASA ASTER, NASA SeaSat-SAR, NASA SRTM, and BNSC CHRIS.
- 20 instruments had ideal spatial resolutions of less than 10 meters, but were only available after a disaster had already occurred through the International Charter or by request from other organizations.
- 30 instruments had ideal spatial resolutions of less than 10 meters but were not available for free in any advertised circumstances.
- Of the instruments currently under development, 12 had ideal spatial resolutions of less than 10 meters but only two have a high probability of the data being available for free; NASA NISAR SAR-L (2020-2025) and NASA InSAR (TBA)

Verification:

NASA's Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global Dataset was found to be the best free and open DEM dataset available, with a moderate spatial resolution of ~ 30 m. The data was collected in over 11 days from the Space Shuttle Endeavour in February 2000, using interferometric synthetic aperture radar (In-SAR) imaging.[4] This data was then processed in ArcGIS to produce a realistic lahar hazard assessment map of the NW flank of Mt. Rainer, WA. The results were then compared to a spatial "ideal" 1 m. airborne LiDAR DEM derived Lahar hazard assessment map of the same area. Both hazards maps were produced using Laharz_py, an ArcGIS toolbox produced by the USGS. The USGS suggests a 1 meter DEM, with a maximum of 30 m.[3]

The best currently available, free and open, SRTM DEM misclassified a significant area compared to the 1 m. Airborne LiDAR DEM. When the inundation area is modeled with an input of 30 million m^3 of material, the differences covered 23.8 square km. A linear relationship was found between the input volume and the number of misclassified pixels using the SRTM DEM.

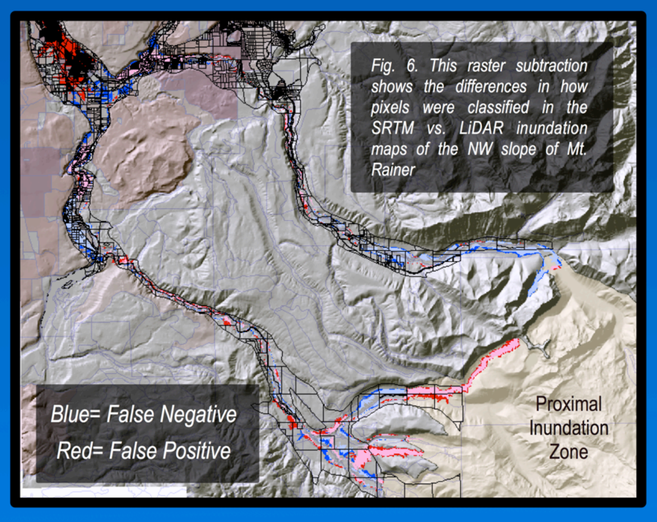


Fig. 6. This raster subtraction shows the differences in how pixels were classified in the SRTM vs. LiDAR inundation maps of the NW slope of Mt. Rainer

Conclusions:

- The limiting factor for preventative humanitarian application of satellite-derived topography is the cost to access the data. There is no apparent technological limitation to DEM production at the desired spatial or temporal resolutions with using hyperspectral, LiDAR, or SAR technology.
- CASIS support of any of these technologies for free and open high resolution DEM production would greatly benefit humanitarian remote sensing. Such a project would be capable of spurring new areas of remote sensing studies by creating a high quality spatial and multi-temporal DEM database for the study of dynamic earth systems, such as mass movements.

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