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GIS RESOURCES

ADVANCES & APPLICATIONS OF GEOSPATIAL TECHNOLOGIES IN EARTH SCIENCES

GEOLOGICAL ANALYSIS USING UAV IMAGERY AND POINT CLOUDS

INSIDE: *RIEGL*'s "Smart Waveform" LiDAR: New Sensors and Systems Offering Unique User Benefits...p 29

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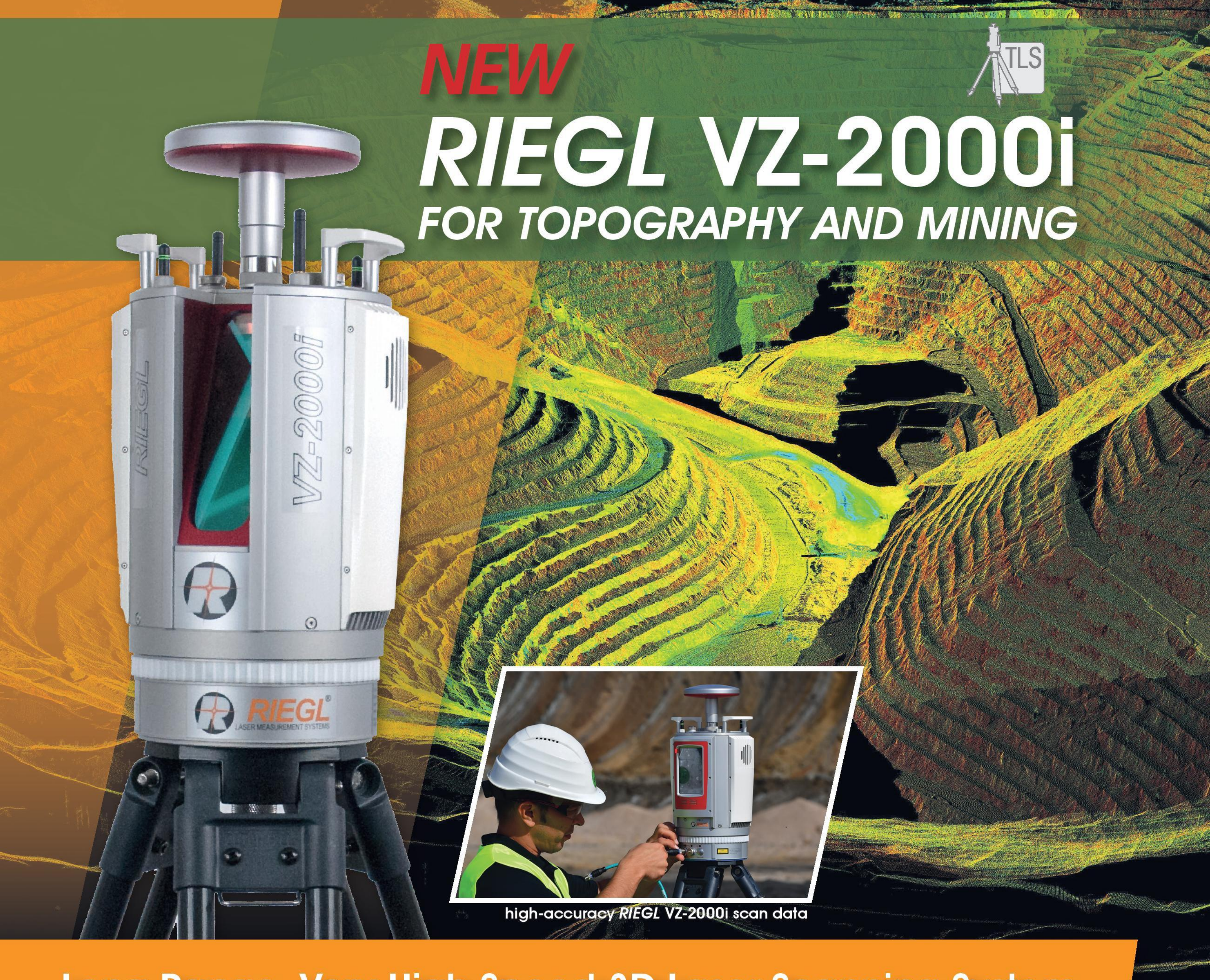
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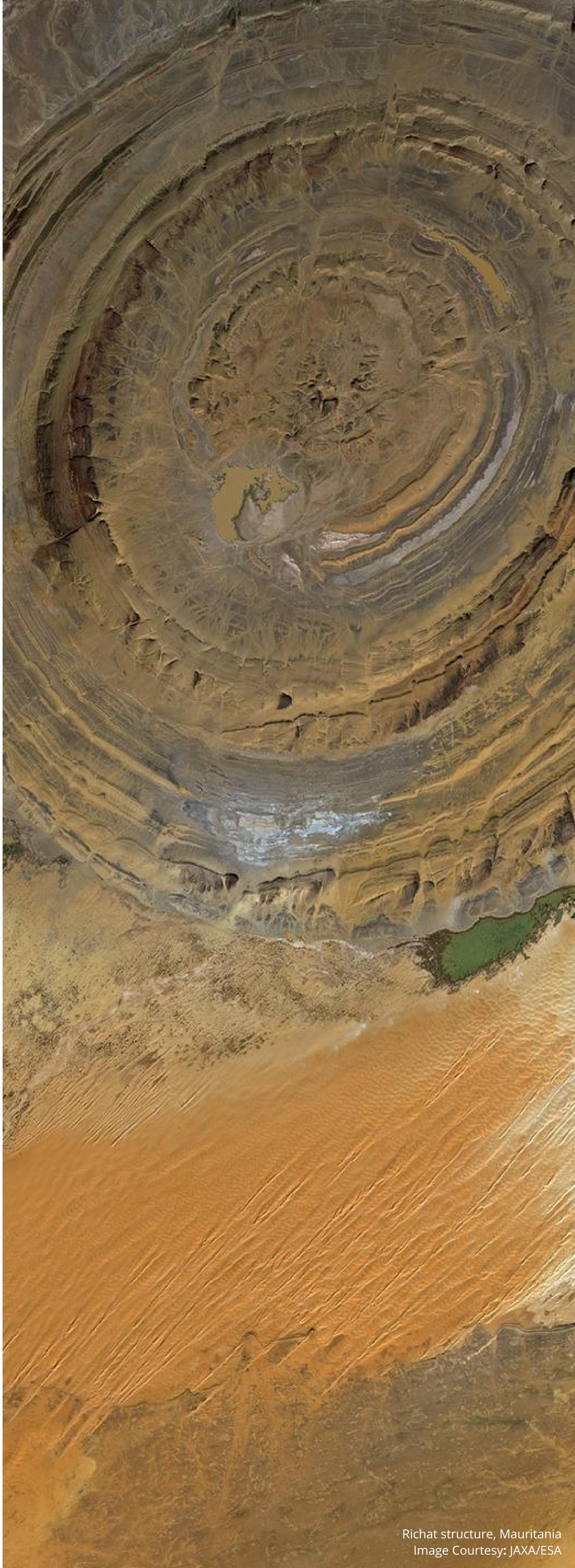

Richat structure, Mauritania
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editor's note

Ashok Prim
Editor

Development Is Required but Environment Preservation Is a Concern

To develop is to move forward. Conserving whatever is left of the Environment is equally important. Development is local/regional. Impact of environmental degradation is global. Development adversely impacts environment. Environment preservation suffers at the cost of development. And we have only one planet.

It is a catch 22 situation. There is no argument against development but should there always be a conflict between development and environment preservation and environment rejuvenation.

Environment Impact Assessment (EIA) is a part of any urban or infrastructure development project. Often not much importance is given to EIA resulting in long term environmental degradation. The need is to have a realistic EIA and then to integrate Developmental activities with environmental concerns so as to achieve both objectives. This is easier said than done but is not impossible.

Smart Technologies, combined with Artificial Intelligence (AI), and Geospatial Information Systems (GIS) must be harnessed to create Infrastructure development plans, alternative Energy generation resources, alternate building materials and all such resources required for development in a manner that their environmental impact is not only minimal but also supports further environment rejuvenation.

We can choose to degrade the environment only at our own peril.

Topographic Analysis for Hazards, Hydrology, and Geomorphology: LSDTopoTools

Image Courtesy: www.wur.nl

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A Revolution in Topographic Data

The last two decades have seen rapid advances in the collection and distribution of topographic data. The first widely-distributed global topographic data-set, GTOPO30, was developed by the United States Geological Survey and completed in 1996. This had a grid spacing of approximately 1 kilometre (or 30 arc-seconds, thus the "30" in GTOPO30) which precluded the identification of all but the largest structures, such as mountain valleys.

The Shuttle Radar Topography Mission (SRTM) was a NASA mission which improved this resolution by an order of magnitude, releasing a near-global data-set with a grid spacing of 90 m. In 2009, the ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) mission, a joint Japanese-NASA mission, produced a 30 metre resolution near-global digital elevation model (DEM), followed by a 30 metre SRTM product released in 2014.

The increase in resolution continues apace, with the release of new products at 12 metre resolution or better in the last few years by the Japanese and German space agencies (ALOS and TanDEM-X missions, respectively). At the same time, large quantities of LiDAR data are becoming available. These data are most often delivered as point clouds and 12-20 points per square metre are now not uncommon.

What does this increase in resolution mean for analysing topography for applications in natural hazards, hydrology, geomorphology and allied fields? A simple answer to that question is simply to look at the features visible from different resolutions. Below we see four images at increasing resolution. At 90 and 30 metre resolution few features are visible, but a linear feature emerges when the resolution is 10 metres, and the linear feature is shown to be controlling drainage network evolution and the paths of channels at 1 metre resolution. This feature is the San Andreas Fault in California (the site is to the West of Bakersfield). High resolution topographic data allows us to see channels, hillslopes, landslides, and faults: these features are difficult, if not impossible, to identify on low resolution data.

Resolution Matters

Naturally, any analysis on topography will depend on the resolution of the topographic data. Several key metrics are very sensitive to data resolution. One metric is flow accumulation. Topography is used to estimate how much water will flow to different parts of the landscape during storms, which has important implications for natural hazards such as landsliding and flooding. An example of this is shown in the figure 1. In 2008 a landslide closed a trunk road, the A57, in Derbyshire, England. Runoff may have contributed to this landslide, and highlighting areas of flow concentration is essential for landslide preparedness. If we run a flow accumulation algorithm on 5 metre and 1 metre resolution data, one can clearly see the differences in flow concentration along the road. Clearly for both flooding and landslide hazard mapping, higher resolution is better.

Big Data

Data distribution has become much smoother in the last few years, with many countries opting to release topographic data as open data. Countries such as the United States, United Kingdom, Italy, Spain, the Netherlands, Germany, and Slovakia have made LiDAR data freely available to users around the world. As we have seen, this high quality, high resolution data has large advantages over older, lower resolution data sets. But these high resolution data sets also pose significant problems. Even 10 metre resolution data becomes unwieldy at regional scales: provincial data at 10 metre resolution can be many gigabytes in size. LiDAR data can exceed a gigabyte within a single drainage basin. Desktop GIS software can struggle with such large data sets, especially for computationally intensive operations like flow routing. Six years ago, we began to develop software, LSDTopoTools, that can operate on powerful computational

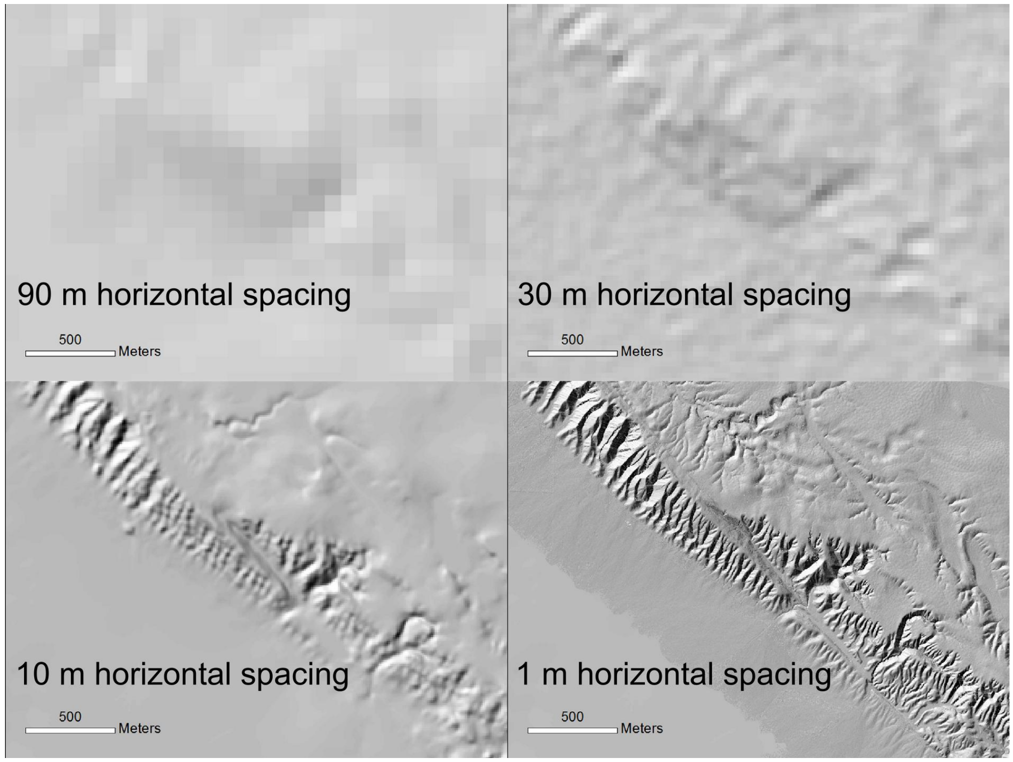

Figure 1. Hill-shade images of the same location in central California at different resolutions. Linear feature trending NW-SE is the San Andreas Fault.

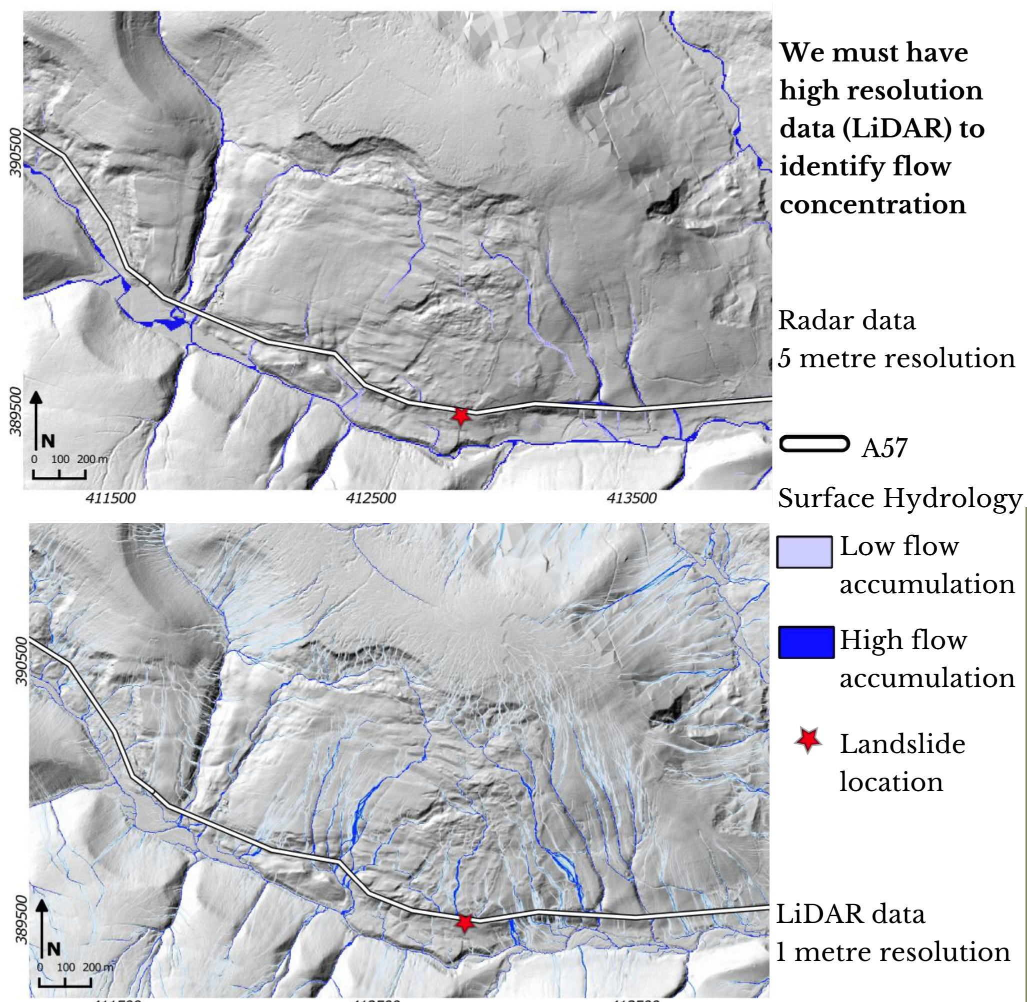

Figure 2. Flow accumulation calculated from a 5 m resolution (top panel) and 1 m resolution (bottom panel) topographic data.

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clusters to enable analysis of regional topographic data sets.

LSDTopoTools

LSDTopoTools is a software package for analysis of topographic data. It was initially developed for scientific research but has more recently been used by regulators as well as national geologic surveys. Applications include hydrology, geomorphology, ecology and soil science.

This software was not only developed to aid analysis of very large datasets but also for a number of other reasons:

- We wanted a file-based interface that allowed perfect reproducibility of analysis. Two users with the same data set and the same input file would create exactly the same analysis: this was essential for scientific applications where other researchers could reproduce our analyses exactly for quality assurance.

- We wanted to automate workflows of our analyses. There are scripting languages in GIS software which can automate analyses, but these are often difficult to share between users, often write large numbers of intermediate files, and are difficult to execute on high performance computing platforms.

- We wanted to implement the latest algorithms for computing various topographic metrics. A good example is the FASTSCAPE algorithm, developed in 2013 by Jean Braun and Sean Willett, which can extract channel networks and channel connectivity many orders of magnitude faster than traditional methods.

These features mean that LSDTopoTools is not meant to replace GIS software but rather to supplement it: output from LSDTopoTools can be read by desktop GIS software but it is intended for highly automated processing of large data sets.

What LSDTopoTools Can Do?

LSDTopoTools has a number of standard topographic analysis features such as flow routing, flow accumulation, and surface metrics. Extraction of channel networks is very efficient in LSDTopoTools so extracting a channel network from large mountain ranges such as the Himalayas at 90 metre resolution may only take a few minutes on a modern server.

The strength of LSDTopoTools, however, is in its more advanced options. We have released packages for extracting channel networks from LiDAR data that can objectively determine channel sources from topographic indicators to within a few tens of meters. Our hydrologic tools are also efficient at collating and sourcing hydrologic data. For example, we recently used LSDTopoTools in collaboration with the Scottish Environmental Protection Agency (SEPA) to map stream power, which can relate to channel erosion potential, for every channel in Scotland.

We have also released packages for exploring topographic indicators of tectonic fault activity. These include a wide range of tools for extracting channel profiles and detecting where rivers cross tectonically active structures. Amusingly, these tools may also be a good indicator of white-water rafting difficulty, as one of our former students, an avid kayaker has pointed out. Sadly, a white-water rafting tool is not yet part of the LSDTopoTools package.

Our tectonic tools also can connect rivers and hill-slopes and can give information such as the steepness of every hill-slope profile in the landscape, as well as allowing us to map bedrock outcrops, and look for indicators of channel migration.

Another component of LSDTopoTools is our topographic floodplain terrace identification tools.

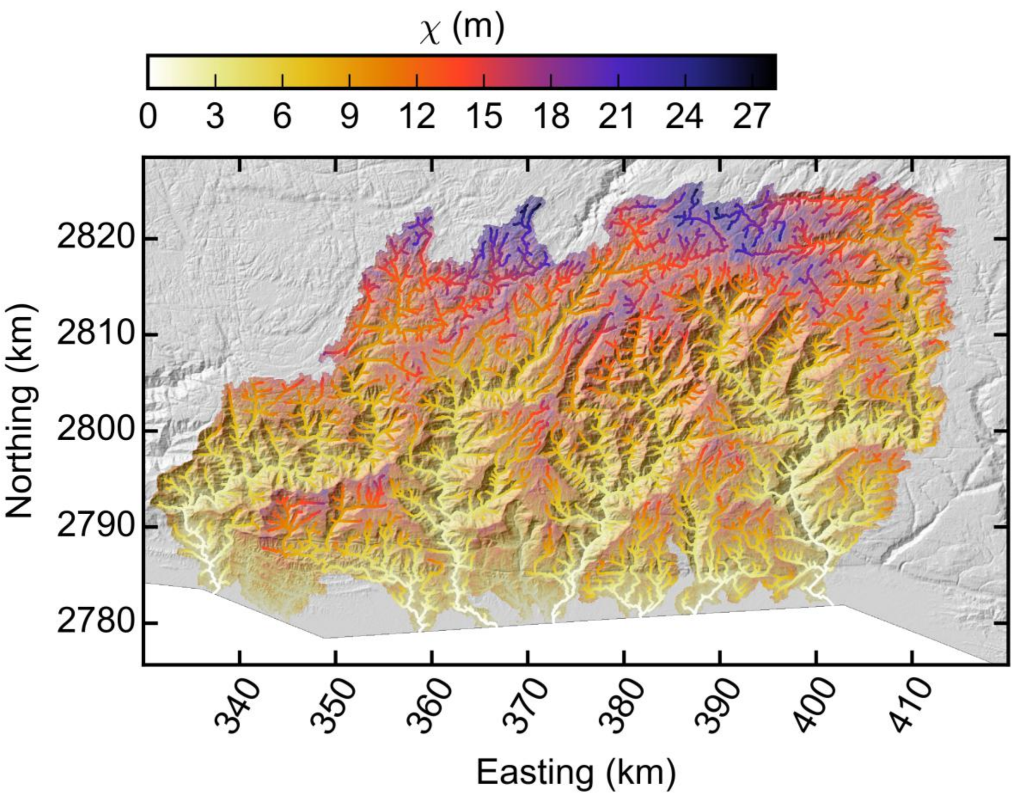

Figure 3. The Shillong Plateau, India. Differences in the χ metric across catchments is used to detect drainage migration

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Our floodplain identification tool uses topographic indicators to delineate flat areas near channels using a series of statistically generated thresholds for relief and slope. The resulting maps are not generated by hydrologic models, so should not be considered flood maps, but compare favourably with flood maps generated by agencies such as the Environment Agency, SEPA, and the Federal Emergency Management Agency. These maps can be quickly generated to provide flood modelers with a rapid assessment of problem areas for further investigation.

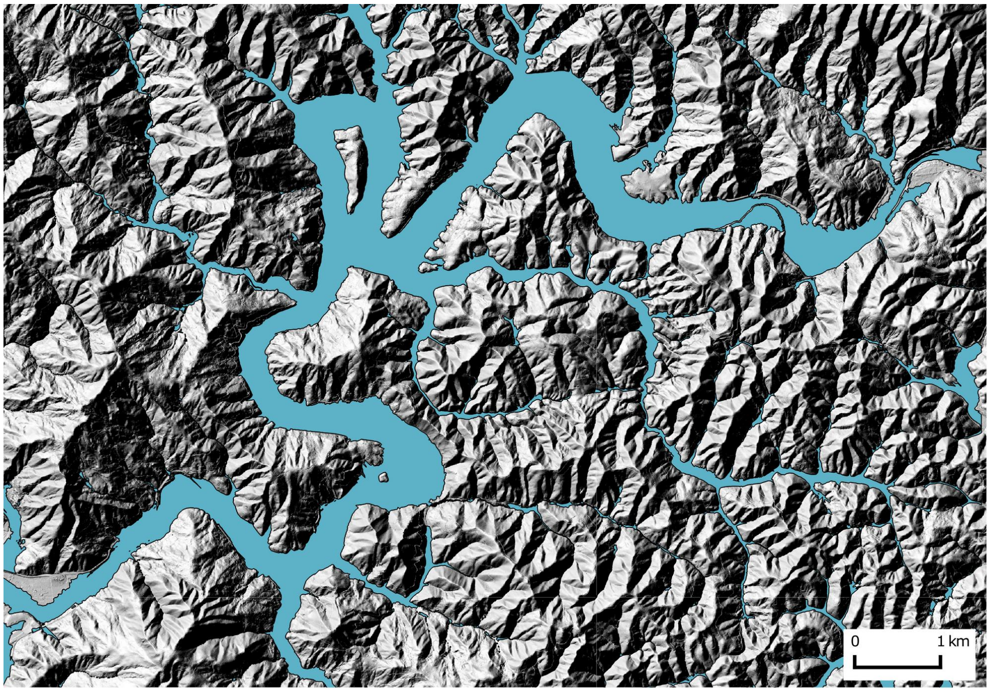

Figure 4. Topographically defined floodplains in the Russian River, California

LSDTopoTools is an open source project which can be found at *https://github.com/LSDtopotools*. The software is under active development and we are developing new tools for natural hazard mitigation, hydrology, tectonic geomorphology and general management of river networks. In the next few years we are keen to expand the user base of the software and lower the barrier from academic use to use by GIS practitioners.

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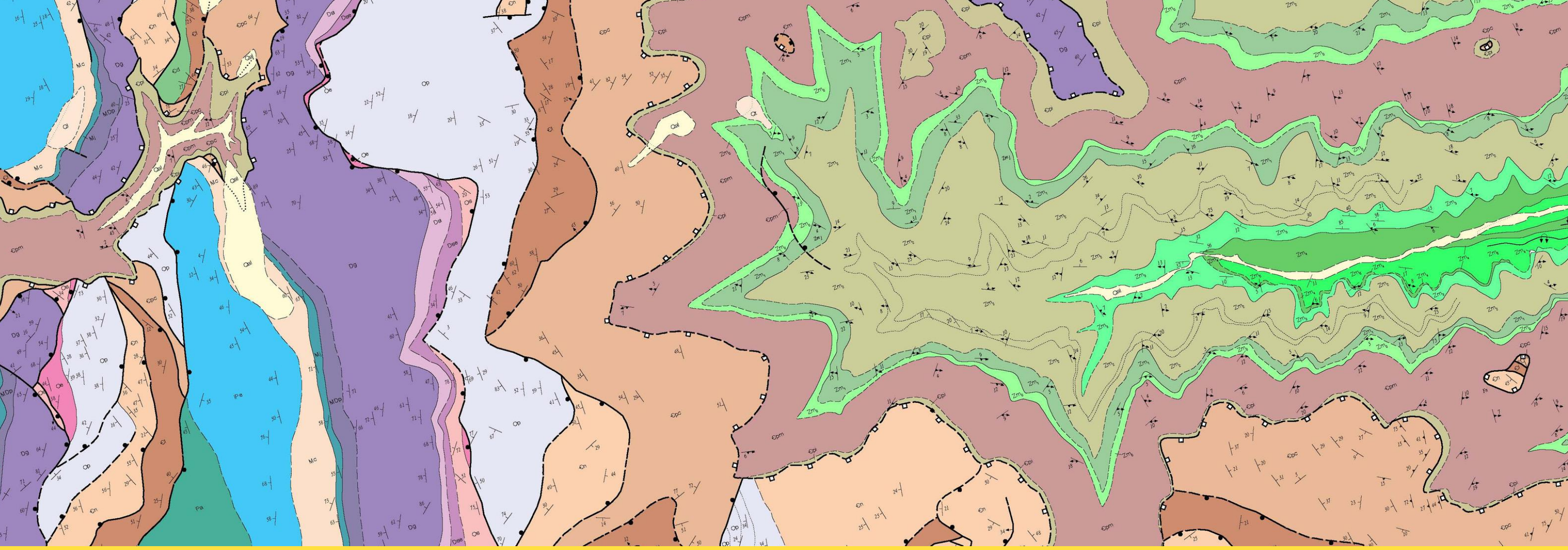

A Digital Mapping Perspective in Geology

Image Courtesy: www.pangea.stanford.edu

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With the advent of mobility, digital mapping has gone one step above the normal mapping process. Geologic mapping is the process by which geological features are observed, analyzed and recorded in the field and showed gradually on a personal computer or in a PDA. The essential capacity of this technology is to produce spatially referenced geologic maps that can be used and updated while conducting fieldwork.

A geological map is a special-purpose map made to show geological features. Rock units or geologic strata are shown by color or symbols to indicate where they are exposed at the surface. Bedding planes and structural features such as faults, folds, foliations, and lineations are shown with strike and dip or trend and plunge symbols which give these features three-dimensional orientations. Stratigraphic contour lines may be used to illustrate the surface of a selected stratum illustrating the subsurface topographic trends of the strata. Isopach maps detail the variations in the thickness of stratigraphic units. It is not always possible to properly show this when the strata are extremely fractured, mixed, in some discontinuities, or where they are otherwise disturbed.

Geological field mapping is the process of selecting an area of interest and identifying all the geological aspects of that area with the purpose of preparing a detailed geological report which must include a map. Good geological mapping should be executed in three phases; planning, data collection, and reporting. A geological map will thus show the various rock types of the region, the structures, geological formations, geothermal manifestations, age relationships, distribution of mineral ore deposits and fossils etc. and all these features may be super-imposed over a topographic map or a base map. The geological map is of great importance to the mining and petroleum industry. Traditionally, the field observations are recorded on the field map and notebooks. These data are then used for the geological interpretation and compilation of geological map, which is manually carried in the office.

Recent developments utilize free and almost universally accessible global terrain models and geological models within Web-based virtual globes, such as Google Earth, ArcEarth, NASA World Wind and Microsoft Virtual Earth. These “geo-browsers” generally support the open-source scripting language KML (Keyhole Markup Language), an XML-derived language that facilitates user manipulation of a geo-browser environment. KML scripting has enabled geoscientists, as well as other producers of spatial data sets, to display field data and maps in a virtual three-dimensional (3-D) interface. Provided the user has an active, reasonably fast Internet connection, the possibilities for exploring an ever-expanding collection of geospatial datasets from locations around the globe are almost unlimited. Users can bypass the requirement for an active Internet connection by loading pertinent data and maps into the cache of a geo-browser, thereby enabling access to a virtual 3-D interface in the field.

Modern Tools and Equipment Used in Geological Field Mapping

- Mobile handheld PDAs (ArcPad, Trimble PDAs etc)
- GPS (Geographic Positioning System)
- Geophysical Testing Instruments like Magnetic Susceptibility Meters
- Exiting Topographical Maps (Survey of India)
- Aerial photograph, Satellite Images, and stereoscope
- Geological Field Note Book
- Brunton compass, Measuring tape, Hand lens
- Geological hammer
- Sample bags, Sample Tags, and Tag Books
- Mineral Hardness Testing
- Range Finders, Field Digital camera, Other Field Accessories

Computer Based Geological Mapping Techniques

Geological mapping is commonly carried out as a multi-stage manual field data collection, manual drafting, validation and compilation processes as shown in the fig. 1. Issues concerning the automation of the data acquisition, data conversion of the existing published maps, digital Image processing, and geological interpretation, validation, and compilation in GIS platform will be discussed in subsequent sections.

Data Sources

The source of required data for geological interpretation, validation, and compilation of geological map can be categorized spatial datasets and field observation data (Figure.1). The existing spatial datasets comprise mainly of existing geological maps (ex: topographic and geological maps), remote sensing, geophysical maps & images and other digital spatial datasets,

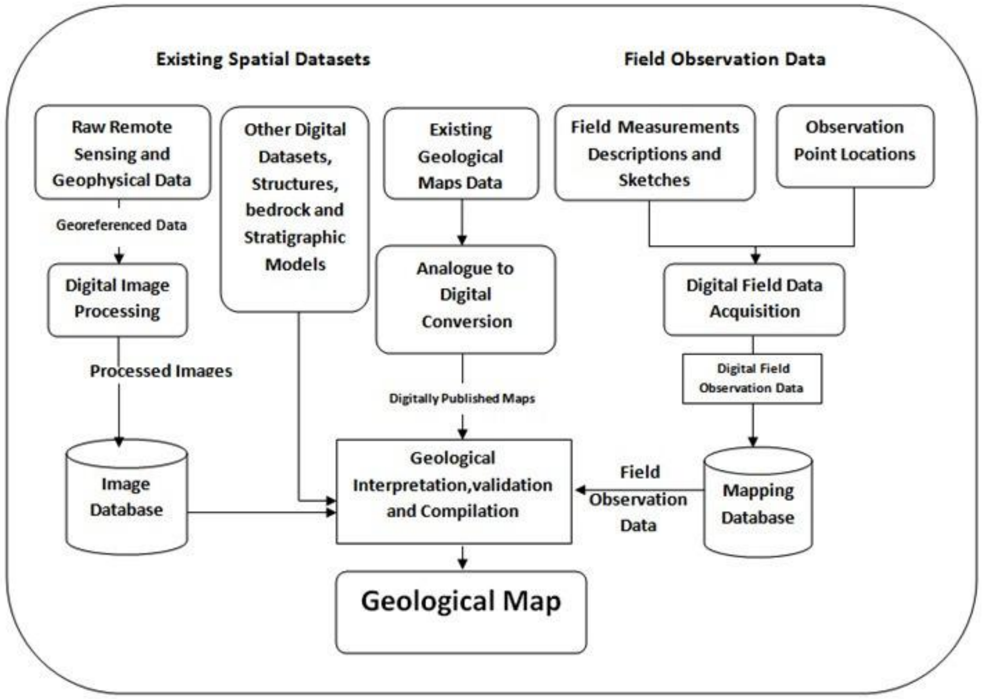

Figure 1. Computer based geological mapping processes

structures, bedrock, and stratigraphic models. The existing published maps are mostly available in an analogue format (printed copies), whereas the remote sensing and geophysical maps and geological models are commonly available in digital format. The field observation data especially consists of the observation point locations, field measurements, and detailed outcrop descriptions and sketches that are recorded at each of the field observation points. Geological Field map and geological field notebooks are generally used to record field observation data.

In order to utilize the above datasets in the based geological mapping, they should be in digital format. To avoid duplication of effort in the field data collection, Digital Field Data Acquisition Field system can be accustomed to recording the field observation data digitally in the field (fig.1).The existing geological published maps can be converted to digital format through the Analogue to Digital conversion system. The remote sensing and geophysical maps & images can be georeferenced to the same geographic coordinate system as the field observation data through Digital Image processing techniques.

Digital Field Data Acquisition

Generally, geological field map is used to record the location of rock outcrops, rock and fossil samples, major contacts, and structures observed in the field. The detailed description and sketches of rock outcrops, field observations and measurements are recorded in geological field notebooks. With the development of the information technology, versatile mobile handheld PDAs, and notebooks, PCs are getting more effective, moderate and low- priced. Geological Field data acquisition software with strong and powerful functionalities have also been developed such as ESRI ArcPad(Bell, 2002), FieldLog, Field Data Recorder (Rockware, 2003), GeoRover (GAF, 2003), GeoMapper Universal, and GSMCAD etc.

Geological field data acquisition systems allow systematic collection of samples and the field observation data using the tailor-made software data entry forms. Systems like ArcPad, GSMCAD, GeoRover, FieldLog, and Field Data Recorder also have GPS interface for retrieval of sample/outcrop location data in Geographic Latitude/Longitude or UTM format. The integration of GPS technology (Lange and Gilbert, 1999) in these systems can speed up the geological field mapping, particularly in open areas. Some of the field data acquisition systems can also be customized to suit the user requirement. For instance, ESRI ArcPad can be customized to allow digital recording of the field observation data (attribute) as well as spatial data (points, lines, and polygons) drawn over different base maps or orthophoto images/Satellite Images.

Overall, the geological field observation data recorded using these systems are managed more effectively using the computer databases like Oracle, IBM's DB2, and Microsoft's SQL Server than the conventional methods. A regular backup procedure can be implemented to avoid any loss of the important geological field observation data. Moreover, the field observation data stored in the mapping database can be readily transferred to the GIS platform for the geological interpretation.

Digital Conversion of Existing Paper Maps

A most important proportion of the attempt concerned in setting up geological mapping system relates to the acquisition of data sets in digital form, and to get all the acquired maps, pictures and spatial datasets in a spatial register (Graeme, 1996). A major proportion of the effort involved in setting up digital mapping system relates to the acquisition of data sets in digital form, and to get all the acquired maps, images, and spatial datasets in a correct spatial register (Graeme, 1996). Two approaches can be used for converting the existing published paper maps into digital format, i.e. manual digitizing and vectorization of scanned maps.

The manual digitizing can be carried out in point, line or stream, Polygon mode. Individual locations (such as well location, sample sites etc) are recorded in point mode as single coordinate pairs. Linear features such as faults, lineament, and geological contacts are recorded in line mode or stream mode. After digitizing, the result needs to be carefully checked and edited to ensure everything has been recorded properly. Utilizing this method systematically and carefully can produce accurate and complete vector data. However, this manual operation is tedious and time-consuming. Optical scanners, either of the rotating drum or flatbed variety, have been used for cartographic data entry since the mid-1960s. The scanner can be used to obtain scanned image of existing paper map. The scanned image is then rectified to a geographic base with ground control points through coordinate conversion (Graeme, 1996). The vector features on this scanned map can then be extracted through the vectorization process (Able Software Corp, 2003). The vector data extracted from the existing published map using the above techniques can then be converted into spatial datasets using sophisticated GIS software.

Digital Image Processing

Digital image processing techniques, such as image registration, image correction, and image enhancement are of particular importance to the geological application of the remote sensing data. The various geometric and radiometric distortions in the remote sensing data can be removed through the image correction technique. Image registration is used to superimpose the satellite image with other spatial datasets (such as geological field observation data, existing published maps, etc.) with geometric precision. This is essential for the accurate geological interpretation using these datasets in the GIS software platform. Prominent features, such as road intersections, and river bends or junctions on the satellite image are identified as ground control points (GCPs). DGPS equipment is then used to obtain the geographic coordinates of these GCPs during the field mapping. By applying for image registration, this satellite image is transformed from the image coordinate to the geographic coordinate based on the GCPs. Image enhancement is utilized to emphasize the important features in the satellite images to facilitate the geological interpretation by the geologist. For instance, edge enhancement is applied to satellite imagery to produce a sharper image with more details such as fractures and joints systems. Spectral ratioing is used to produce a remote-sensing image that is quite independent of illumination conditions. Remote Sensing Software packages that can be used for the digital image processing include ERDAS Imagine, GRASS, SAGA, ER Mapper, ILWIS, ENVI, Geomatica, ECognition and Idrisi.

Geological Interpretation and Compilation in GIS Environment

Generally, the geological mapping is carried out manually in the office after the field mapping schedule. The field observations recorded on the geological field map and field notebooks, as well as any other existing published maps and satellite images are used in the geological Interpretation. Preparation of these datasets to the correct scale and format is necessary prior to the geological interpretation. The appropriate maps and satellite images may require being enlarged or reduced to a correct scale. Geological field mapping traverses and recorded field measurements (such as dip/ strike etc) are then manually plotted at the same scale as the other maps. All these maps and satellite images, as well as the field measurement sketches and plots, are then placed over each other correctly on a light table for geological interpretation. During the compilation of geological map, the geological contacts shown on the field maps are manually traced to a new Mylar sheet. Inferred faults/folds and inferred geological boundaries are then drawn on the Mylar sheet based on the interpretation using all the available datasets.

The geological field observation data stored in the mapping database can be used to produce various layers of field observation maps (such as strike/dip, lithofacies, fossils etc.) that superimpose each other accurately in a geographic coordinate system. All the detailed description, sketches, plots and photographs recorded at each of the field observation points can also be accessed easily by selecting the spatial features shown on these map layers. Any data updates made to the geological field observation data in the mapping database will automatically update the map layers and their related data.

Any additional important digital spatial datasets (such as satellite and geophysical images, published maps, geological models, etc.) in the proper format can also be loaded as appropriate map layers in the GIS. For instance, remote sensing data from aerial or space platform can be used to delineate vertical to high angle faults or suspected fault. Lithological information can also be deduced from a number of parameters observed on satellite images, such as general geologic setting, structural features, drainage, landform, soil and vegetation, and spectral characters.

The geological interpretation based on multidisciplinary data in the GIS platform has not been fully automated yet. However, the geological interpretation can be carried out by the geologists more accurately and efficiently under the GIS platform than the conventional method, through effective use of the digital spatial datasets from various disciplines.

The GIS also support to speed up the interpretation, compilation and production of the geological map. The geologists can compile the geological map entirely within the GIS platform, without the need of preparing draft drawings to be digitized or drafted by conventional method. A number of a commercial GIS software package are available, which include ESRI ArcGIS Desktop, QGIS, MapInfo, GRASS, MapWindowGIS, uDig, OpenJUMP, Cadcorp, Manifold, and SuperMap.

Discussion

Traditionally, geological mapping processes can be enhanced through the use of information technology. A number of issues need to be considered for the successful implementation of the computer-based geological mapping. These include the acquisition of digital spatial datasets and selection of suitable tools for the geological field data acquisition and geological interpretation.

The digital spatial datasets consist of one of the most important components of the geological interpretation in the GIS platform. Care must be taken to ensure that these digital datasets are captured properly and accurately. Proper map projection and a coordinate system must be used during the digital field data acquisition and conversion of printed maps to digital format. Further, metadata for these spatial datasets must be available for the geologist to select suitable spatial datasets for the geological interpretation.

The selection of computer hardware & software also plays an important role in the successful implementation of digital geological mapping. The field mapping conditions need to be considered during the selection of the hardware (handheld or notebook computer) for the digital field data acquisition. The selected hardware must be able to withstand these field conditions throughout the field mapping phase. The filed data acquisition hardware and software must be compatible with selected hardware/software, user-friendly and robust, so that field mapping process and geological interpretation to can be carried out smoothly and seamless transfer of field mapping data between the systems.

Conclusion

The geological field observation data can be collected more systematically using the tailor-made data entry forms provided by the digital geological field data acquisition system. This digitally collected field observation data are managed more effectively using the computer database than the conventional methods. The integration of GPS technology to the system also helps to accelerate the field mapping in open areas.

The digitally acquired geological field observation data can be utilized readily for the geological interpretation in the GIS environment. Different kinds of map layers can be generated easily from the digital geological field observation data in the mapping database. Therefore, the geological interpretation can be carried out accurately and efficiently in the GIS platform.

The outcome of the geological interpretation can be utilized readily in the compilation of the geological map, which eliminates the redundancy of preparing draft drawings. Finally, an update to the geological map can be carried out easily. The geological map can also be published as printed copies using plotters, or as digital geological map stored in CD-ROMs and DVDs.

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(Declaration: This manuscript is a compilation of the works done by many authors across the globe & the authors have ensured simplification for better presentation & readability)

Vulnerability and Risk Analysis of Female Population in Landslide Affected Areas of Kohima Town, Nagaland

Image Courtesy: www.dipr-manipur.gov.in

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There is an increasing need and interest among the researchers and government sectors to identify and pursue disaster risk reduction which is both risky to the community as well to what degree it influences an individual. Not everyone is affected by any kind of disaster in the same manner and therefore to understand the variation in terms of susceptibility to damage vulnerability assessment is required.There is a need to study gendered based research as female's vulnerable populations are even more exposed during disasters occurrence in general. This study highlights the importance of mapping of demographic vulnerability especially in regards to female vulnerability. Landslide occurrences are very frequent in this part of the study area and there have been various researches based on the landslide hazard zonation but a research gap in relation to demographic vulnerability still persist. Therefore, the main objective of this study is to generate the database in GIS platform to find out female vulnerable in landslide-prone areas for simulation and assessment of risk analysis.For this study, the total female population 28941 out of total population 59636 of ten wards out of Kohima Town, Nagaland was considered for analysis.

Study Area

The study area includes 10 wards of Kohima Town (13.06 sq. km.) which is the capital of Nagaland and includes parts of the National Highways 39 & 61 respectively was selected for the study. The study area is incorporated in the Survey of India and lies between north latitudes 25°48'37" to 25°51'37" and east longitudes 94°03'40" to 94°06'24". The study area is a hill town with maximum and minimum heights of 1440 m and 940 m respectively above mean sea level.

Vulnerability and Risk Analysis-Female Population

GIS database for the study area was created with the help of the already created landslide hazard zonation map of 5 classifications ranging from very low, low, moderate, high and very high values and population data from Census data of India, 2011 which was updated with the data from the ward council till 2015. The demographic vulnerability was considered from the population data. The total vulnerable population is 59636 where out of which more than half population is of female population of 28941. Risk analysis is defined as the use of available information to calculate the risk to individuals, population, property or the environment from hazards. In the study, the risk map was created by overlaying with the best-fitted model of landslide hazard zonation map with the demographic vulnerability ranked from very high to very low values. Since population data is not spatial data therefore for risk analysis, the population of each 10 ward was integrated with the different classification of hazard with the total area.

Conclusion

Vulnerability mapping was created which indicates, the female population under the risk of the different 5 level of classification. In order to define risk classes, actions to reduce vulnerability may change the unacceptable risk to an acceptable risk. There are several limitations in the available data to carry out micro-level analysis, which was also considered when preparing the risk analysis results. However, the final results show that the investigated processes pose high risks to the community, to some part of it. In particular, the areas such as A.G Colony, Paramedical, and Hospital colony are places with very high risk. There are cases where the areas below the hazard zones, shows no or very low risk such as Agri/Forest colony and Lower Chandmari with a very low level of risks should not be neglected on the final risk maps. But even though it shows low result risk, one must be aware that there always exist risks which may lead to future disasters where recommendations on how the applied methodology and its results can be improved can be followed. One of the most important aspects of improving the results of this study is to more accurately define the return periods of the respective occurrences of landslides and keep a check on the female population vulnerable to a landslide. The participation of women in the planning, designing, implementing and monitoring emergency programs and rehabilitation projects is still not yet addressed in the study area.

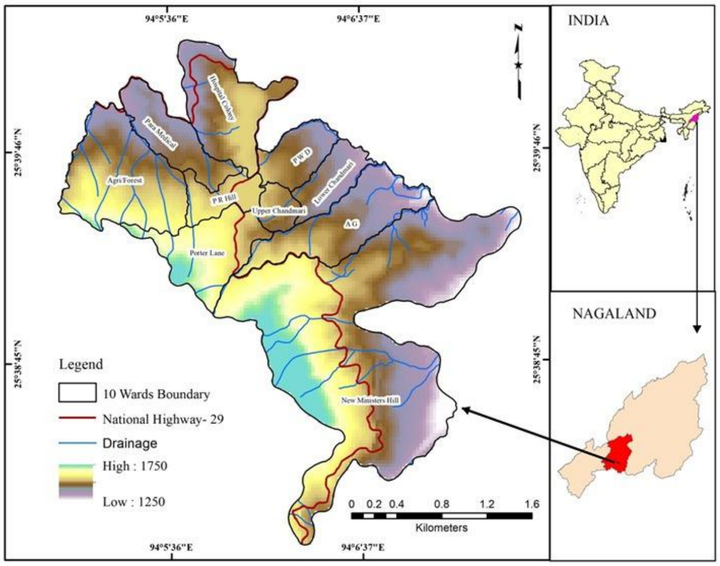

Figure 1. Study area: Kohima, Nagaland, India

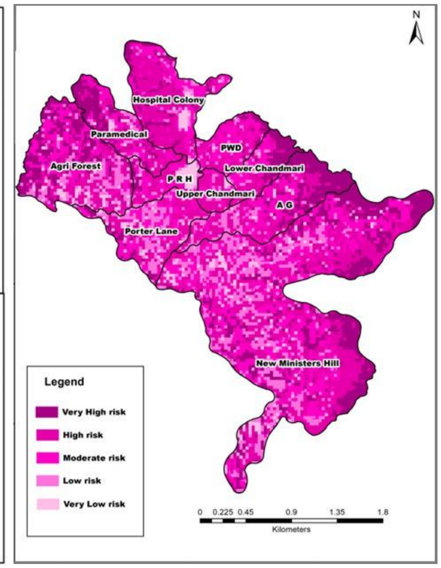

Figure 2. Female population at risk

Ward name and number	Total vulnerable population	Total female	Risk level	Population at risk	Female at risk	Ward name and number	Total vulnerable population	Total female	Risk level	Population at risk	Female at risk
A G (No. 15)	7970	3787	Very low	159	75	P.R.Hill (No. 19)	3652	1672	Very low	769	352
			Low	1100	523				Low	503	230
			Moderate	2011	955				Moderate	1081	495
			High	2201	1046				High	1046	479
			Very High	2499	1188				Very High	253	116
Agri/Forest (No. 17)	7789	3822	Very low	524	257	PWD (No. 11)	5305	2604	Very low	54	26
			Low	1467	720				Low	560	275
			Moderate	1724	846				Moderate	2291	1124
			High	1947	955				High	1846	906
			Very High	2127	1044				Very High	555	272
Hospital Colony (No. 10)	4991	2376	Very low	237	113	Paramedical (No. 18)	4864	2345	Very low	178	86
			Low	435	207				Low	544	262
			Moderate	1299	618				Moderate	1212	585
			High	2331	1110				High	1389	669
			Very High	690	329				Very High	1541	743
Lower Chandmari (No. 13)	3288	1702	Very low	65	34	Porter Lane (No. 14)	6167	2929	Very low	489	232
			Low	313	162				Low	1700	808
			Moderate	976	505				Moderate	1765	838
			High	741	383				High	1804	857
			Very High	1194	618				Very High	408	194
New Ministers Hill (No. 16)	11683	5791	Very low	505	250	Upper Chandmari (No. 12)	3927	1913	Very low	147	72
			Low	2226	1104				Low	606	295
			Moderate	2896	1435				Moderate	1258	613
			High	3581	1775				High	1916	933
			Very High	2474	1226						

Table 1. Ward details and risk analysis of the total vulnerable population and female at risk

Acknowledgments

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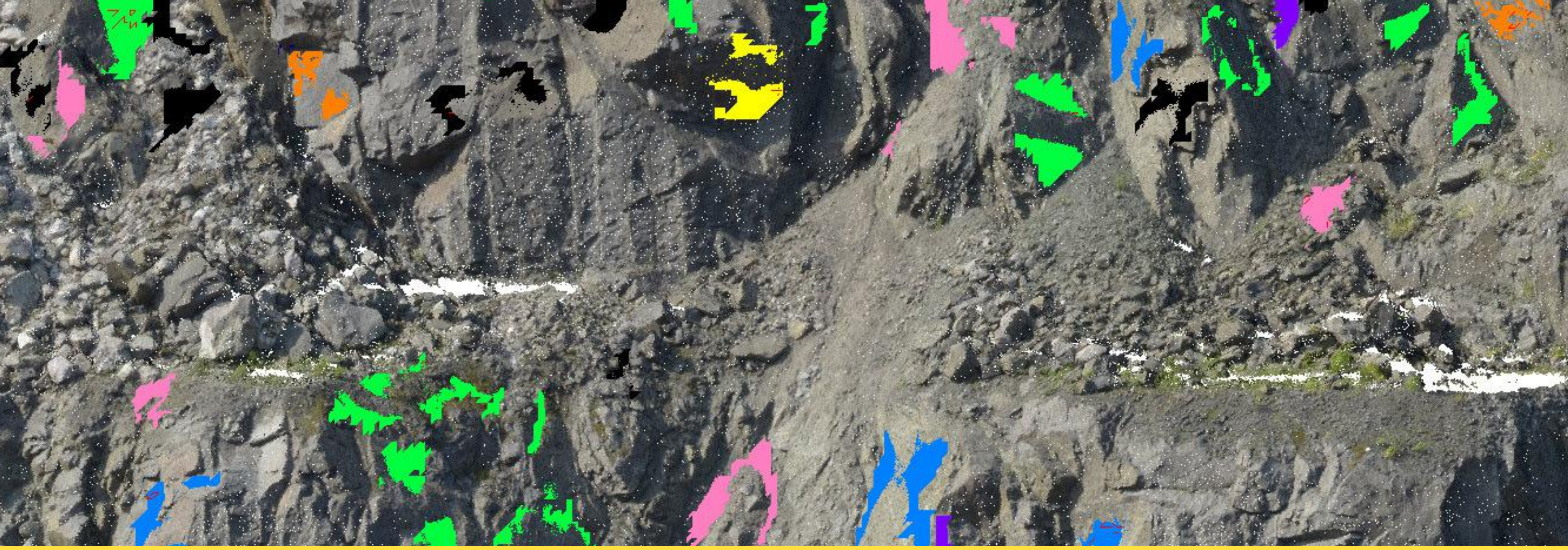

Geological Analysis Using UAV Imagery and Point Clouds

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Unmanned Aerial Vehicles, typically called UAVs, are quickly becoming prominent in the earth sciences and engineering fields. Their ability to quickly and simply collect high resolution, multi-perspective, multi-sensor imagery for site characterization is unparalleled. When you add the 3D deliverables that photogrammetric processing produces from the imagery, you have a powerful tool at your disposal to analyze a site's geology. This analysis can be done through visual inspection, through image and remote sensing analysis, and through geometric point cloud and digital elevation model (DEM) analysis. Depending on the sensor used, the analysis can extract and map digital features for lithology, mineralogy, large- and small-scale structure, geomorphology, water, temporal changes, and more. In this article, I will relate UAV methods with existing image and remote sensing analysis methods, discuss a method of geological site characterization using UAVs, and mention some of the challenges using UAVs for this work.

Although the use of laser scanners (LiDAR) on UAVs is possible, I do not consider them in this article. For one, they are not prevalent yet. Two, they are not as precise as terrestrial LiDAR yet. And three, if you only have a LiDAR on a UAV and not a good high-resolution camera, you will miss the critical image-based geologic features that are obvious to both your eye and to the image-processing software.

Remote Sensing Analysis

Image analysis technology has been used extensively for many decades now, with satellite and airborne sensors providing multiple data products to analyze. Satellites and airplanes deliver data products using multiple sensors, both passive and active. Satellite interferometric synthetic aperture radar (InSAR), multi and hyperspectral imagery, and airborne imagery and LiDAR have been processed for GIS for many decades now, with continuous improvements. These data provide DEMs, orthomosaic imagery, deformation monitoring, and many other deliverables. With these products, geological features can be identified and mapped, creating advanced geologic maps for vast areas and at high-resolution. With the advent of UAVs, these principles are being applied to lower level air-based image data, but with the addition of more 3D needs for modeling and analysis.

Using LiDAR for geological analysis of discontinuity properties has been around for over a decade now. The true 3D nature of the LiDAR point clouds has permitted excellent analysis and mapping of geomorphological and structural geology data. A few commercial software and freeware exist to conduct this analysis. The accuracy and validity of this digital methodology has been proven. The use of this method for production and consulting rock mass characterization has only slowly grown over this period due to the large nature of the data, often resulting in both slow processing times and cumbersome data management. However, the processing software has recently been relieving this pain with level-of-detail data rendering, taking advantage of computer graphics cards and limiting the amount of detail displayed and processed based on distance to the scene and the area visible.

A UAV Method for Site Characterization

Here, I will describe a UAV workflow for analyzing and extracting geological data using UAV captured data in a GIS/CAD environment. This workflow describes from field to office, from image data to digital geologic features, interpretation, and models.

1) Flight planning

- a) Use existing geologic maps, imagery and site data to design automated flight plans.
- b) Optimize your flight plan to give you the resolution and details you really need for the project.
  - i) Pick the right camera for your job.
    - • Consider camera specifications, image overlap, distance from the ground, lighting, time of day.
  - ii) If you maximize, not optimize, your resolution, your field, processing and analysis time will increase accordingly.
- c) Plan enough ground control points (GCP) and consider availability of real-time kinematic (RTK) and Differential-corrected Global Navigation Satellite System (GNSS) for positioning to ensure your latitude, longitude and elevation accuracy meets your project requirements.
- d) Complete flight planning FAA (Federal Aviation Administration) safety requirements & notifications.

2) Field data capture

- a) Always perform preflight safety checks and local notifications and communications.
- b) Check the site conditions that day.
  - i) Consider time-of-day lighting, angles, reflections, clouds, weather, and operations.
- c) If it is not safe or the data capture conditions are poor, you may need to reschedule.
- d) Fly your routes and capture your intended images.
- e) Manually fly hard-to-reach perspectives for truly 3D data capture.
- f) Onboard the UAV, a GNSS and IMU (inertial measurement unit: accelerometer, gyroscope, magnetometer) record positions and camera orientations for each image capture.
- g) Check image quality right away in the field so that you can fix mistakes in the field before wasting your field time and bringing large amounts of bad data to the processing stage.
- h) Download geo-tagged and orientation-tagged images from the UAV or upload directly to the cloud or a server if your system has the capability.
  - i) Run another image quality check, this time to remove bad images before processing begins.

3) Photogrammetric data processing

- a) A method of stereographic triangulation calculations is performed on two or more overlapping images covering some common objects and unique points.
- b) Images with georeferencing data will be processed to create 3D point clouds, orthorectified mosaic images and DEMS.
- c) Georeferencing accuracy improvements are made using the ground control points (GCP) surveyed in the field and clearly visible in the images.
  - i) Some software now can automatically locate and adjust the data from uniquely coded GCP in the images and the list of corresponding survey coordinates.

4) Point cloud cleaning, editing and registration

- a) With the full point clouds, it is best to quickly optimize the data to the minimum required level of detail.
  - i) Doing this at the beginning of the workflow speeds up every downstream.
  - ii) Too often, this part is neglected or not done sufficiently, resulting in noisy, inaccurate and data-heavy surfaces.
    - • This makes downstream data usage slow, cumbersome and often deters users from taking advantage of the full information being presented to them.
- b) Cleaning and editing:
  - i) Photogrammetric point clouds typically have denser points than the accuracy and precision of the data permit and it makes the files larger and slower than they should be.
  - ii) Different cleaning algorithms exist to:
    - • Remove noisy points, outlier points that fall too far away from a certain range of the local statistical range of the data.
    - • Remove points based on spacing.
      - (a) Point density, where points are removed where the density is greater than specified.
        - • For example, if you know your accuracy is 10 centimeters (cm), then you may choose to set your point cloud density to 5 or 2.5 cm.
        - • Or if you need one-foot contours, you may choose to reduce your point cloud density to 0.5 or 0.25 feet.
    - • Other options exist depending on the software.
  - iii) Editing:
    - • Separating and merging point clouds.
      - (a) Specific jobs with the data downstream have different requirements.
      - (b) Optimize your file sizes by cropping and merging data where needed and set

the noise reduction and densities according to the requirements.

- However, if you create many data deliverables, you now have more files overall to store and manage, and even though they are smaller optimized files, you should consider your today data storage and management capabilities.

c) Internal data registration:

i) Assuming the data has been adequately georeferenced to the project requirements for spatial accuracy, there is often a need to co-register the 3D data for temporal change analysis

ii) When running change detection, you need to register the two clouds or surfaces to each other to make sure the areas that have not changed are within a desired tolerance of each other, otherwise you will not detect true change in your space.

iii) Best fit algorithms and manual registration if required to marry the 3D clouds or surfaces before comparing.

iv) Either one of the time periods needs to be considered the truth, or you don't care which is true and just marry them as best together to highlight the changed areas.

d) LiDAR can also be used to improve 3D registration for change detection and overall accuracy.

5) Image and point cloud analysis

a) UAV data has the advantage over LiDAR data in that it provides full image coverage of sites, while LiDAR typically has single 3D points attributed with image color or reflectivity.

i) What this means is that with UAVs, you get a true high-resolution 3D point cloud and true high-resolution imagery.

ii) Both can be analyzed separately and together for classifications, filtering and editing, feature extraction and terrain analysis.

b) I will mention a few image analyses that can be useful from UAV data.

i) Classification

- Pixels can be trained and classified to attribute various vegetation, buildings, man-made ground, bare earth and geology types.
- If multispectral, hyperspectral and other specific sensors are used, then possible classifications increase.
  - (a) It is possible to map the various observable lithologies and mineralogies, alteration and weathering fronts.
  - (b) Both automated and manual mapping of geology.

ii) Feature extraction

- Images can be analyzed for delineating areas of common classifications or analysis results, allowing attributed point, linear or polygonal vector data creation.
- Geologic lineations and polygons of differing surface geology can be automatically mapped this way.

iii) Change detection:

- Image-based changes.
- Polygons of measured change.
- Raster change maps.
- Minerals, vegetation, moisture, weathering, material depositions.

c) Point cloud analysis:

i) Classification

- This classification is based on local topographic changes and lowest points in a local topography.
- Classification scheme defines low and high vegetation, buildings, bare-earth and outliers.
- Topographic analysis can be conducted to extract geologic features.
  - (a) Fault and landslide scarps and offsets.
  - (b) Lineations.
  - (c) Karst features.
  - (d) Structural trends.
  - (e) Hummocky terrain and levees for landslides and debris flows.

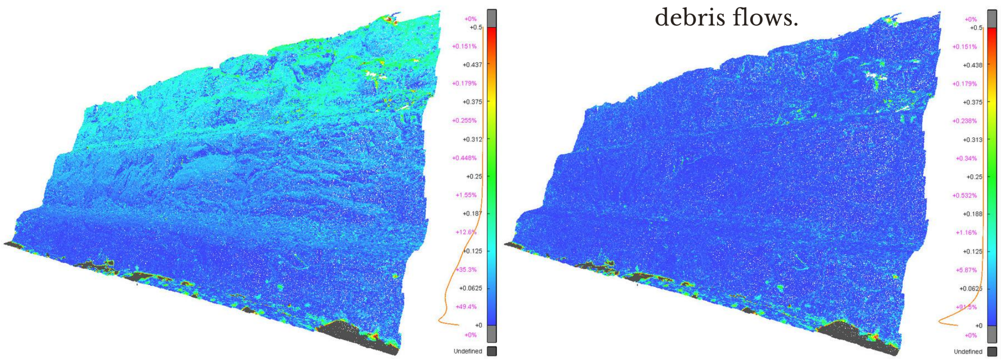

Figure 1. UAV point cloud registration using terrestrial LiDAR

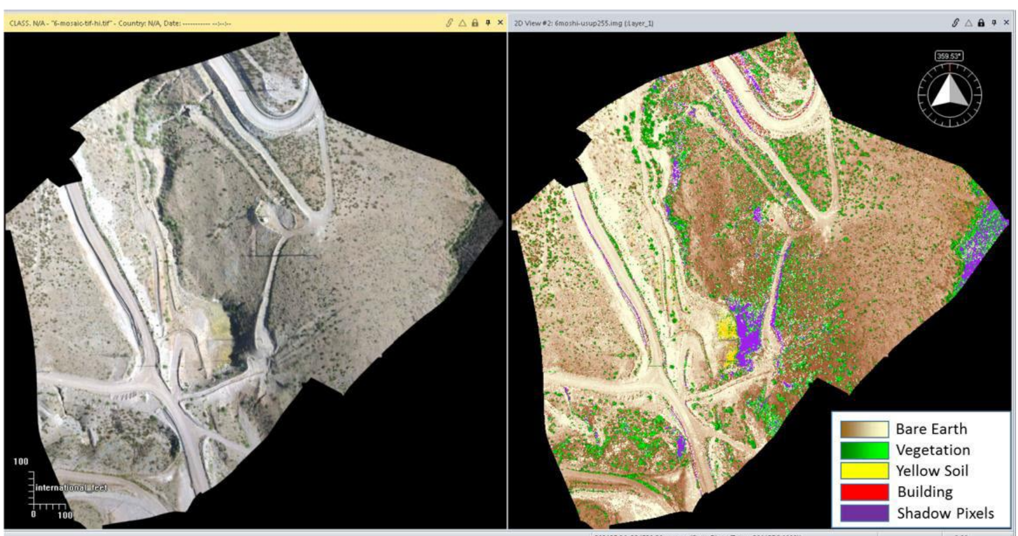

Figure 2. Classification of UAV data using image analysis

• Change detection:
  (a) Geometric/terrain change.
  (b) Mass-wasting events.
  (c) Deformation.
  (d) Erosion and hydrologic feature changes.

d) Joint image and point cloud analysis.
  i) In some software, the results of both image and point cloud analysis can be attributed to the other data type.
  ii) Point clouds can be attributed with the image analysis for the corresponding pixels and vice versa.
  iii) The combined data can be combined for an improved classification to enhance vegetation removal from UAV data.

6) 2D and 3D modeling

a) 2D GIS
  i) In traditional GIS software, all the above-mentioned products can be imported, visualized and analyzed with geological and other GIS layer maps.
  ii) Analysis can include
    • Comparing locations of existing and new geologic features and domains.
    • Correlating new geologic finds with known data and updating models and maps.
    • Further change detection.
      (a) Volumetric change measurement.
        • Updating of site plans based on the new geology data.
  iii) However, for more detailed 3D analysis on a small scale and for the subsurface, the data should be brought into a true 3D environment.

b) 3D GIS/CAD
  i) In the true 3D environment on a digital outcrop model, you can conduct more detailed rock mass characterization and outcrop structure mapping.
  ii) With high-resolution point clouds, small scale geologic structure is visible as fracture planes and linear traces day lighting in an outcrop.

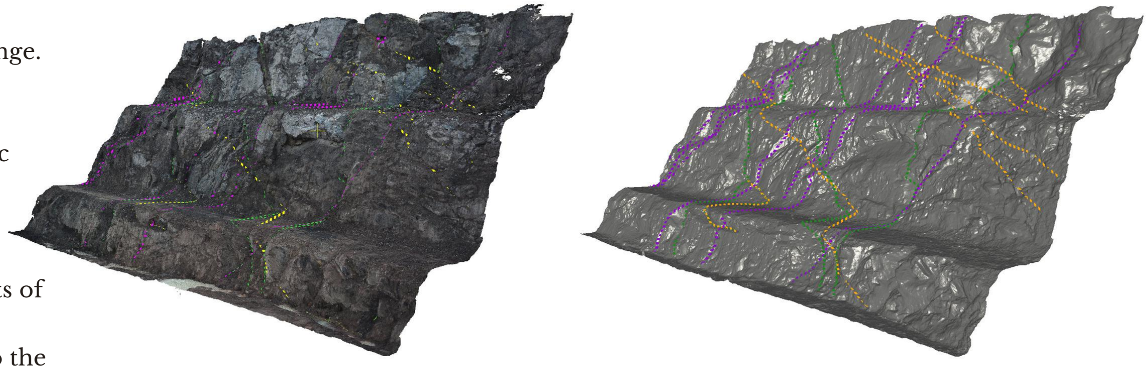

Figure 3. Fault digitization using 3D color UAV point cloud and mesh digital terrain model

  iii) These features can be automatically and manually delineated and mapped using specialized software.
    • Polygons and polylines attributed with orientation data, strike and dip/dip and dip direction.
    • Discontinuity spacing.
    • Roughness.
    • Aperture.
    • If multi or hyperspectral imagery is used, then discontinuity fill mineralogy could be determined.
  iv) Combine the new features with existing 3D models.
    • Add to the 3D geologic structure and domain models.
    • Update models and corresponding plans based on those models.

Challenges with UAVs

UAVs are a convenient way to collect large amounts of very informative data quickly, but challenges must be noted. These challenges can take a well-intended plan to add UAVs to improve your workflow to a waste of time and money that may not give you a return on your investment and, worse yet, may not be usable.

Flying UAVs is a challenge for a few reasons. Battery life for UAVs is notoriously low, often limiting flight times to 15 minutes or less. This makes it hard to capture large areas in a reasonable time frame. Recently, longer flight times have become more prevalent, with flights an hour or longer being more common.

On the data capture side, flight plans, cameras and pilots are not perfect and imperfect data is common. To start out, you may be fine to use a cheaper UAV and camera, but you may also quickly realize that your data requirements exceed your system's capabilities. For photogrammetric processing to work accurately, the objects in the images must be sufficient resolution to pull out details without distortion from improper camera lenses. Flights must be flown at the proper distance from the object not only for the required overlap, but also to obtain the small enough pixel size to extract the level of detail that your project requires. However, collecting more images and higher resolution than you need, will slow down every step of the processing and analysis because of the unnecessarily huge size of the data.

Site conditions are also a limitation of UAV data collection. Since UAVs are mostly using passive camera sensors, they rely on ambient light conditions to absorb reflected light. This means that they cannot operate in the dark without powerful lights and are highly affected by diurnal light changes from sun angles to clouds. Vegetation is a big challenge for UAVs because imagery does not penetrate vegetation the same way laser scanning does. Because of this limitation, getting bare-earth data is much harder, if not impossible with UAVs. However, flying to capture oblique angle images and utilizing the above-mentioned joint multispectral imagery and 3D point cloud vegetation classification can improve vegetation removal. And surfaces of water and snow can be too mobile, too homogeneous and/ortho reflective, inhibiting the photogrammetric automated detection of matching points, required for generating accurate 3D geometry recreation.

Photogrammetry processing is a slow process. Taking the right number of images with the required overlap and resolution ensures you won't process more than you need to, but it still won't be fast. Algorithms and computing technology are not available yet to make this a real-time process, which is highly desired for instantaneous onboard surveying and mapping. If you don't need the most detailed point cloud or DEM, then make sure you don't choose the densest settings in the software.

As mentioned in the methodology section, the point cloud and imagery data is difficult, if not impossible, to use if not adequately simplified for the downstream uses and project requirements. Although newer, level-of-detail (LOD) file formats are rapidly increasing the size of data that can be viewed in software, it is still best practice to optimize your data to your needs and cut the unnecessary fat. Even with these new formats and computer power, not all software in the workflow or all calculations will run with the heaviest UAV-based point clouds and images. These files are still large by today's standards of large data, with files in the 10s to 100s of gigabytes (GB) becoming common. Along with this large data challenge, comes the challenge of data storage and sharing. The larger the files, the harder it will be to up store, upload and download, always taking up time and clogging up your network bandwidth for other work. In addition to simplifying data, optimizing data can mean taking advantage of the LOD file formats mentioned above as well. These formats are highly compressed, typically taking an ASCII point cloud file to 5% or less of its original size, meaning a 10 GB point cloud goes down to at least 0.5 GB. Hexagon Point Clouds (HPC) and Enhanced Compressed Wavelets (ECW) imagery are two examples of these highly compressed file types. And speaking to the LOD capabilities, this means that users will stream the data to their viewers, only rendering the details they need based on the area they are observing and how zoomed in they are. Your computer power is not wasted on trying to process and visualize details you cannot even see anyway.

Conclusions & Future Work

UAVs are being used more and more for geologic investigations and site characterization. However, there are challenges that exist that make full implementation challenging and risky. Some of these challenges are simply in the technology and the fact that the initial photogrammetry processing is slow. Some of the challenges are issues you can address by understanding your requirements and optimizing entire workflow to meet those needs, reducing file sizes and downstream processing times. Future work will likely be related to UAVs with combined cameras and LiDAR, longer flight times and real-time data processing and mapping. Currently, Hexagon Mining is working on improving the workflow detailed above, by integrating systems from the UAVs to the processing and analysis to the 2D and 3D modeling. The more automation and integration there is, the faster and less error-prone the data and deliverables will be, resulting in faster and improved decision making from UAV data.

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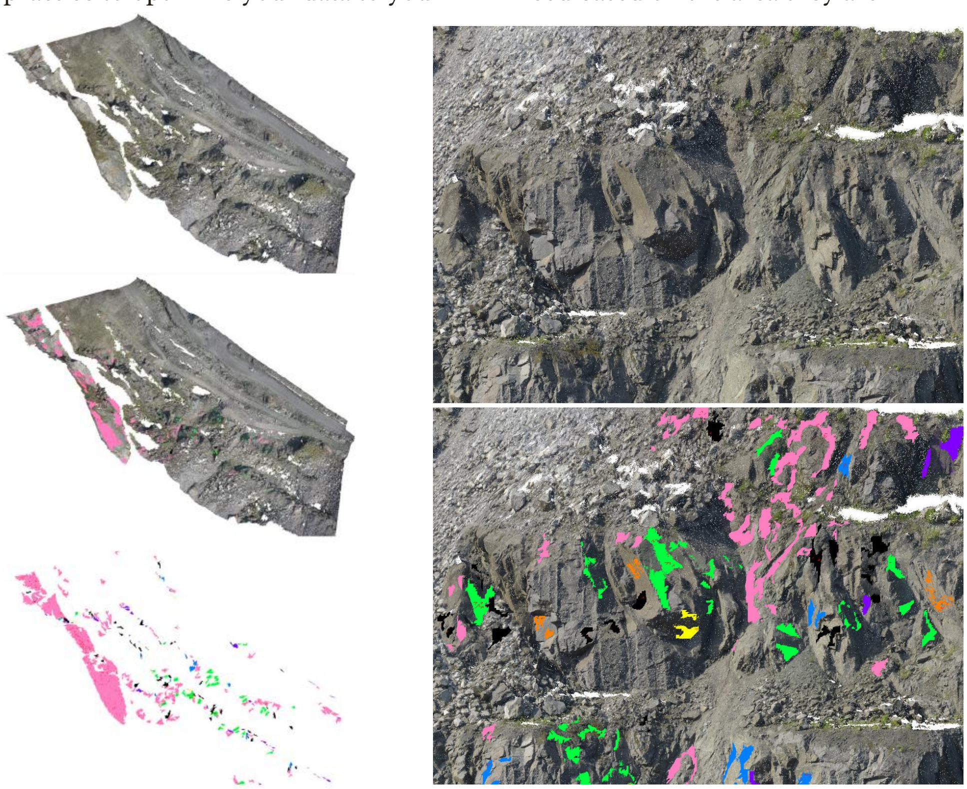


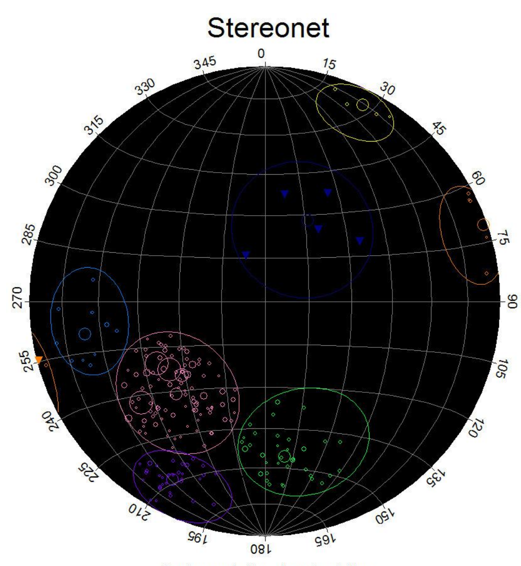
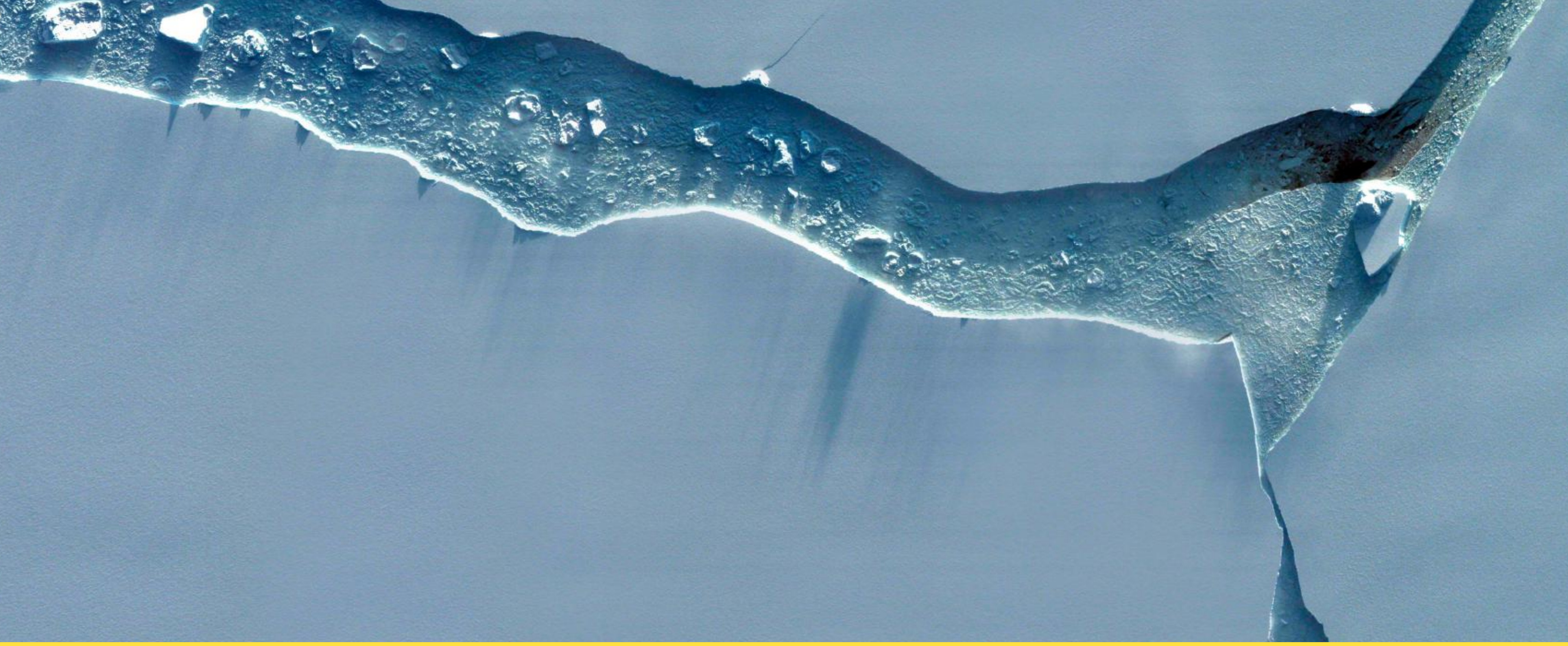


Figure 4. 3D color UAV point cloud model: map view showing automated geologic structure extraction (left), face view showing the same (middle), and resulting stereonet (right).



Massive Antarctic Iceberg's Changes Monitored from Space

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More than a decade ago, scientists began monitoring the developments of a large crack in the Larsen C ice shelf in Antarctica. In mid-July, one of the largest icebergs ever recorded broke free from it,leaving the area at its lowest recorded extent.This giant iceberg, known as A68, is estimated to cover an area of around 6,000 sq km. Since the ice shelf is already floating, the newly calved iceberg didn't affect sea level. However, it changed the outline of the Antarctic Peninsula forever and it could bring further consequences.Water currents and winds might eventually push the A68 iceberg north of the Antarctic where it could become a hazard to shipping. Additionally, as the Iceberg A68 moves away into the Weddell Sea, it will expose around 6,000 square kilometres of sea floor that have been shielded by ice for up to 120,000 years, presenting an exceptional chance to study the ecosystem beneath before the loss of the ice causes it to change.

Antarctica contains about 60 percent of the Earth's fresh water rooted into its massive ice sheet. Ice shelves hold back the glaciers behind them, regulating the speed at which they flow into the ocean. Understanding how ice shelves melt can help scientists improve estimations of how the Antarctic ice sheet will respond to a warming ocean and contribute to sea level rise. It also will shape up global models of ocean circulation by providing a better projection of the amount of fresh water ice shelf melting adds to Antarctic coastal waters.

But, how can we timely monitor such a remote place, with extreme weather and poor light conditions, as Antarctica? Satellite data has proved to be one of the most cost-effective tools so far.

Synergistic Tipping and Cueing To Understand Larsen C Ice Shelf's Evolution

Following the recent developments in Antarctica, Deimos Imaging launched a campaign to monitor the Larsen C ice shelf and the freshly calved A68 iceberg with Deimos-1 and Deimos-2. It is specially complicated to get pictures of Antarctica in July and August because of its long winter nights and the frequent cloud cover.Scientist had to rely mainly on polar satellites such as Sentinel-1, which use radar to see through dense cloud cover and regardless light conditions. Nonetheless, Deimos Imaging managed to capture exclusive optical imagery with Deimos-1 and Deimos-2.

Deimos-1 was specifically designed to

timely monitor vast regions, thanks to its very wide 650-km wide swath. Additionally, Deimos-2 very-high resolution data is a key source of information to detect changes in incredible detail that complement ground assessment information, without the costs and risks of having people on the field. Thanks to the very high revisit frequency of both sensors, 2 days average revisit time worldwide for Deimos-2 and 3 days for Deimos-1, a synergistic use of both sensors ensures a remarkable capacity of imaging the Earth's surface cloud-free.

The images captured over Antarctica's Larsen C Ice Shelf since the calving of the Iceberg A68, allowed to perform a change detection and a multi-temporal comparison of the berg's trajectory.

In this campaign, a synergistic tipping and cueing was carried out, collecting information and coordinating activities between Deimos Imaging's sensors. Thanks to its wide swath and high revisit time, Deimos-1 pinpointed where the main developments were going on in the Larsen C ice shelf and its surroundings; then, this information was used to task the very-high-resolution Deimos-2 over the identified areas, to get much more detailed imagery that allowed a very accurate measurement of the crack's extension. This procedure of tipping and cueing was applied reversely too, when Deimos-2 captured a fraction of a large area and there upon Deimos-1 was tasked to cover its whole extent.

The ability to record a sequence of images over time at different spatial resolution and the utilization of the tipping and cueing technique are especially useful for environmental monitoring and change detection. In this case, it enabled to track and capture the most relevant developments, both in context and in detail of the changes in Antarctica's Larsen C Ice Shelf.

The imagery captured by Deimos Imaging served scientist to confirm that the gap between the Iceberg A68 and the Larsen C ice shelf is widening, raising concerns that the massive berg may be soon drifting away in open Sea.

This proved the value of geospatial information for environmental monitoring and change detection, especially in remote areas where it is difficult to get up to date information otherwise. Satellite data is an easy-to-use and cost-efficient monitoring tool that allows to measure and detect changes in our planet at a global scale and thus, a key tool for decision making.

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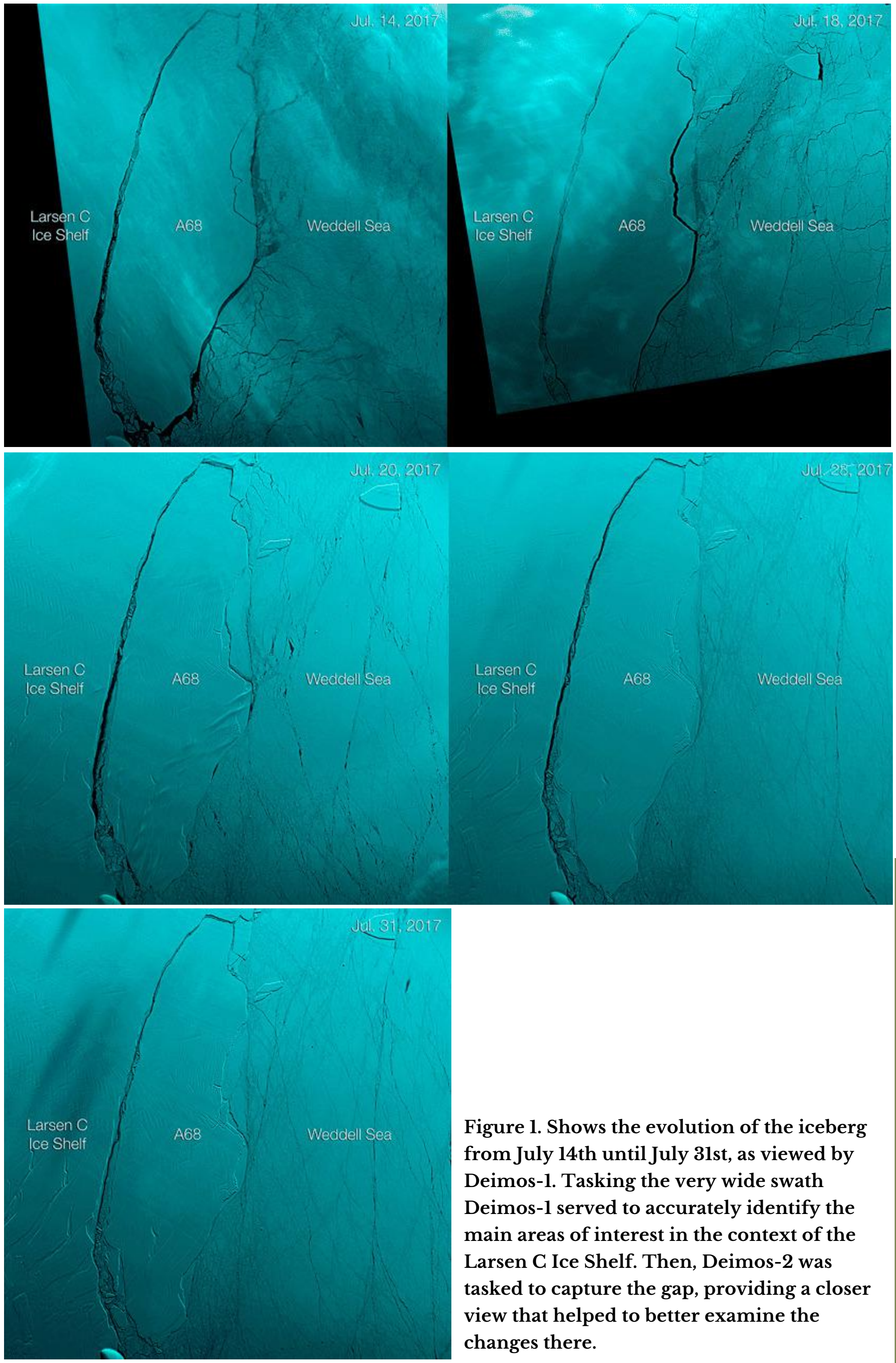

Figure 1. Shows the evolution of the iceberg from July 14th until July 31st, as viewed by Deimos-1. Tasking the very wide swath Deimos-1 served to accurately identify the main areas of interest in the context of the Larsen C Ice Shelf. Then, Deimos-2 was tasked to capture the gap, providing a closer view that helped to better examine the changes there.

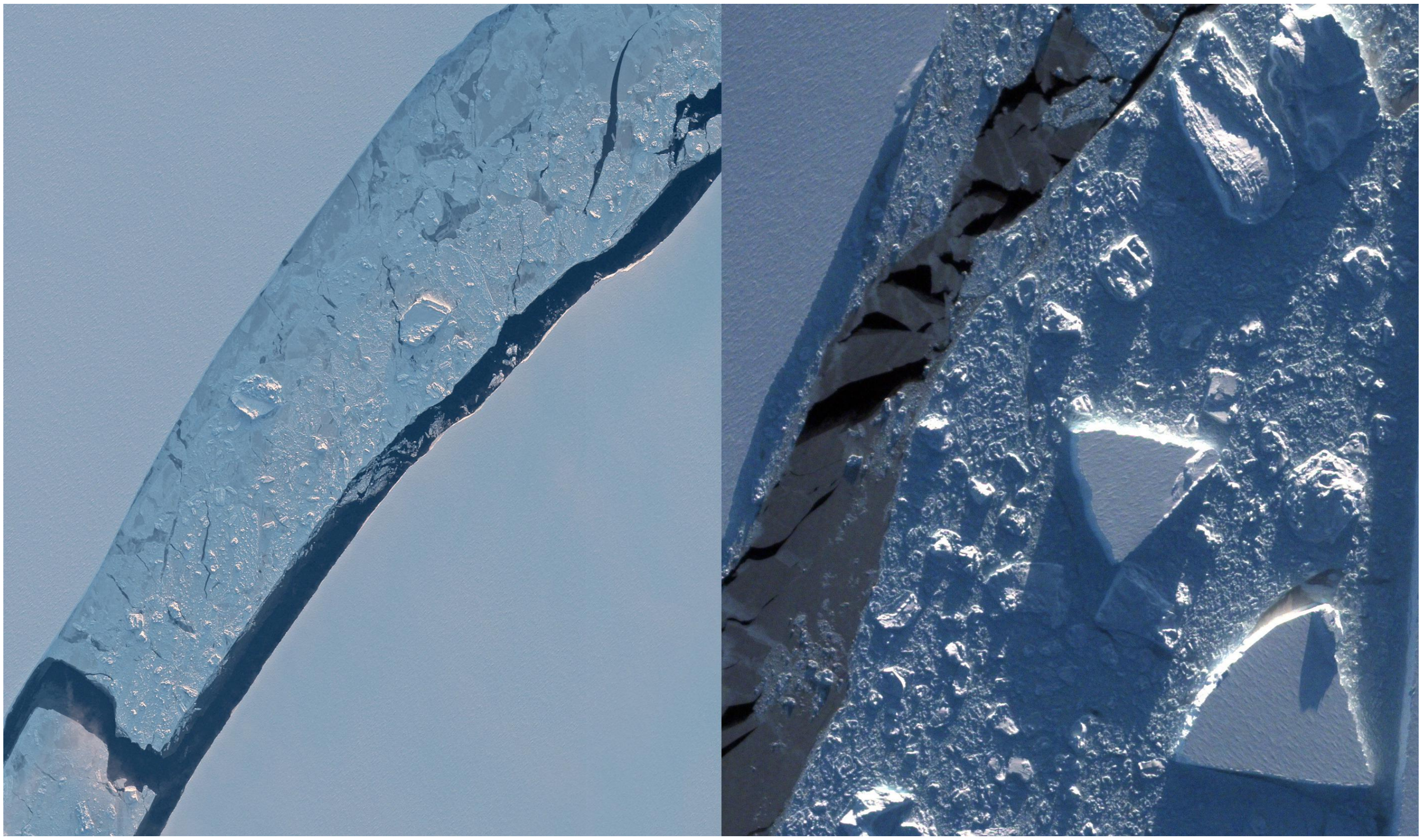

Figure 2. Shows zoomed-in views of the crack between the Antarctica's Larsen C ice and iceberg A68 captured by Deimos-2 on July 16 (left) and July 31 (right), 2017. The images show a lot of ice melange in the gap and blocks of ice falling away giving the berg's edge an angular appearance.

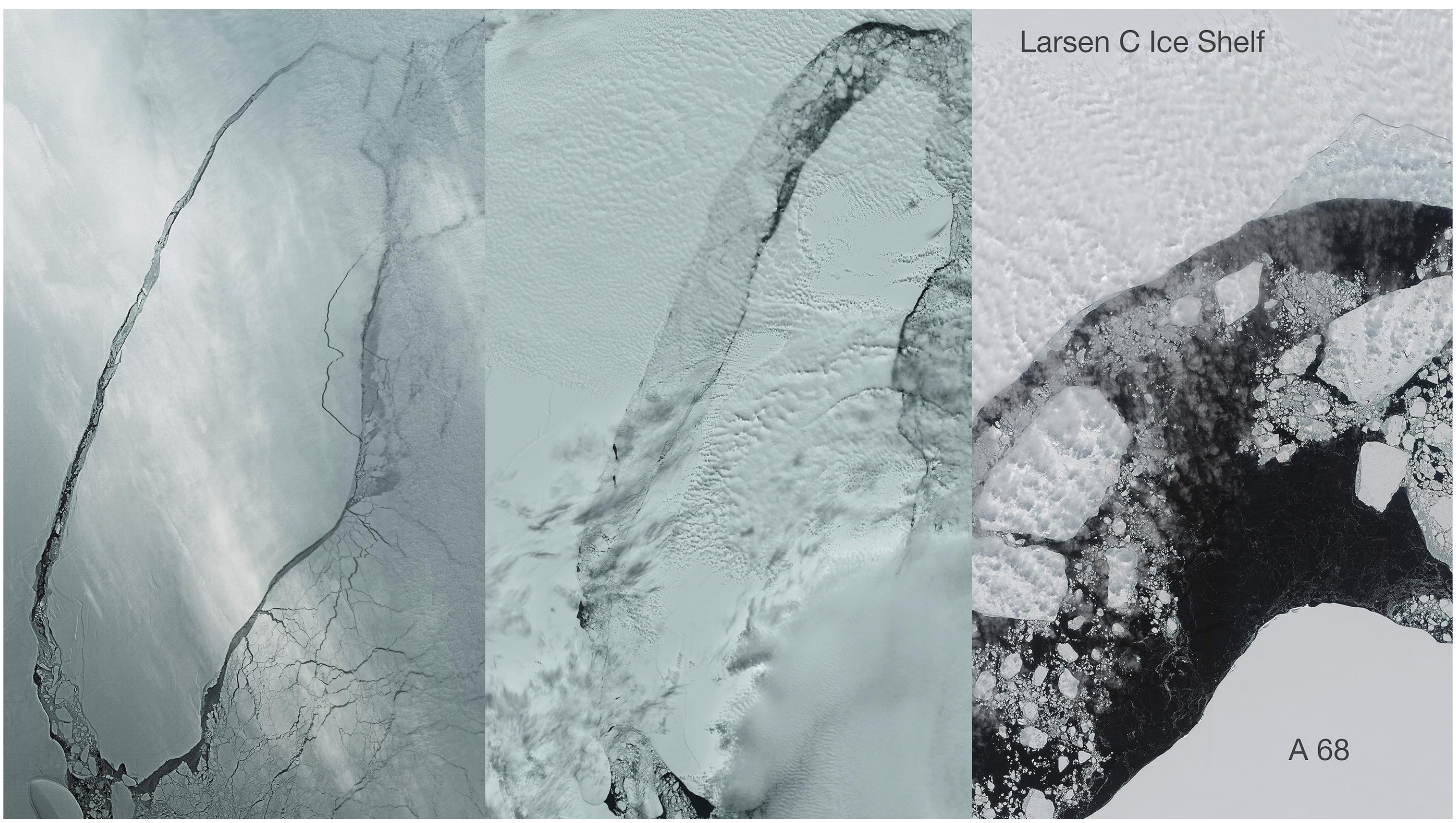

Figure 3. Shows two Deimos-1images acquired on July 14 (left) and on November 25 (centre), 2017; and a Deimos-2 image (right) captured on November 20, 2017. A multitemporal comparison between the Deimos-1 imagery as well as analysis of the very-high-resolution Deimos-2 data allowed to identify a big widening of the cracks between the shelf and the iceberg.

Hurricane Harvey Flooding in Houston Analysis Using KOMPSAT-3

Image Courtesy: Richmond Times-Dispatch

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Colorado, USA

Hurricane Harvey, which began on August 17th and ended on September 3rd, was the costliest tropical cyclone on record, inflicting nearly $180 billion (2017 USD) in damage, primarily from widespread flooding in the Houston metropolitan area, breaking the previous record set by Hurricane Katrina.It was the first major hurricane to make landfall in the United States since Wilma in 2005, ending a record 12-year span in which no hurricanes made landfall at such an intensity in the country. In a four-day period, many areas received more than 40 inches (1,000 mm) of rain as the system slowly meandered over eastern Texas and adjacent waters, causing catastrophic flooding. With peak accumulations of 60.58 in (1,539 mm), Harvey was the wettest tropical cyclone on record in the United States. The resulting floods inundated hundreds of thousands of homes, displaced more than 30,000 people, and prompted more than 17,000 rescues.

SI Imaging Services has provided two KOMPSAT-3 images of 70 cm resolution over the flooded area which was respectively captured on May 4th, 2017 (before the flood) and September 1st, 2017 (after the flood) to AllSource Analysis for an analysis report.

The images were also provided to Earth-I, and everyone can access their platform to see changes over the flooded area due to Hurricane Harvey through the following link: *http://apps.earthi.world/*

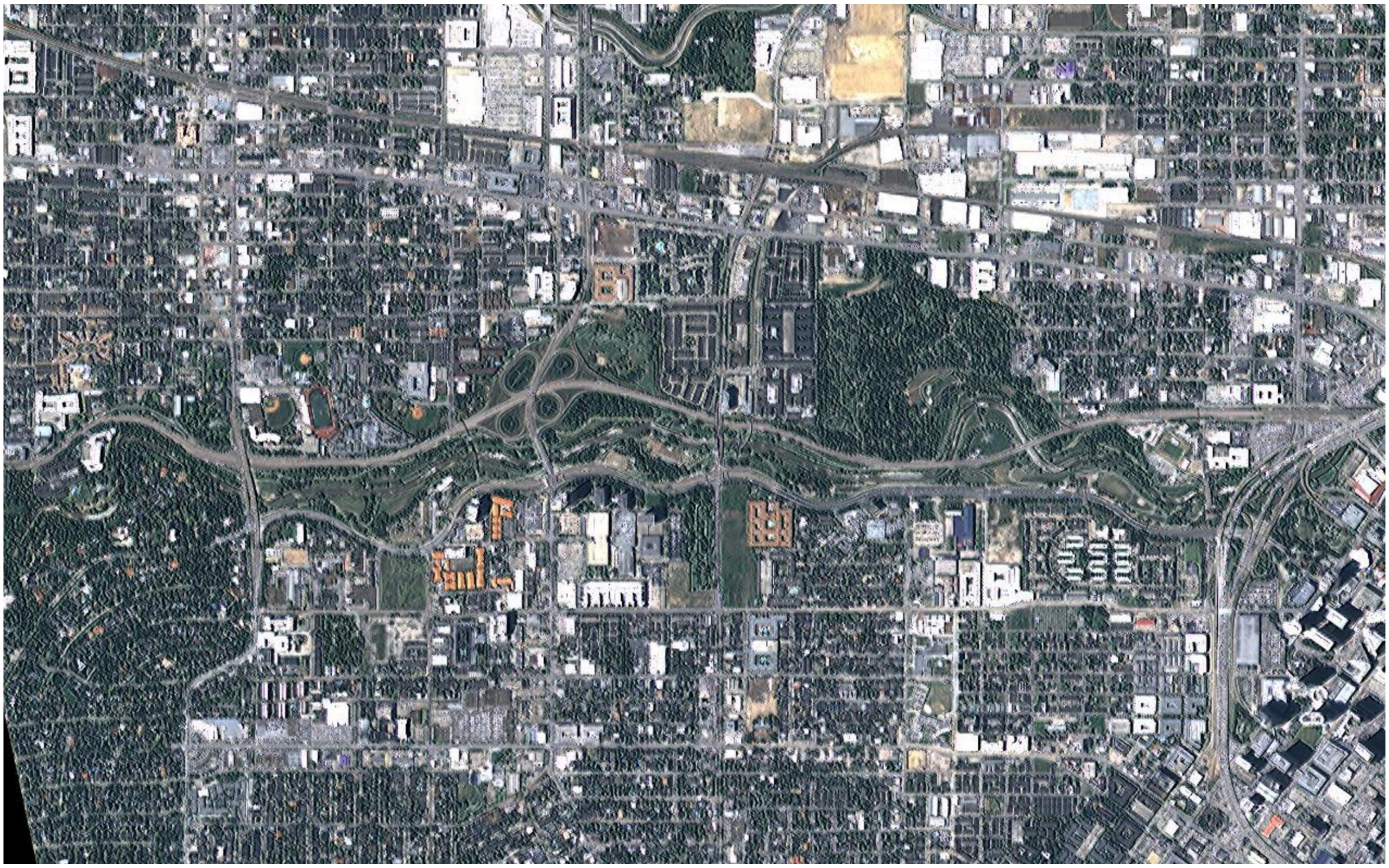

Figure 1. Before image of flooded area along Memorial Parkway

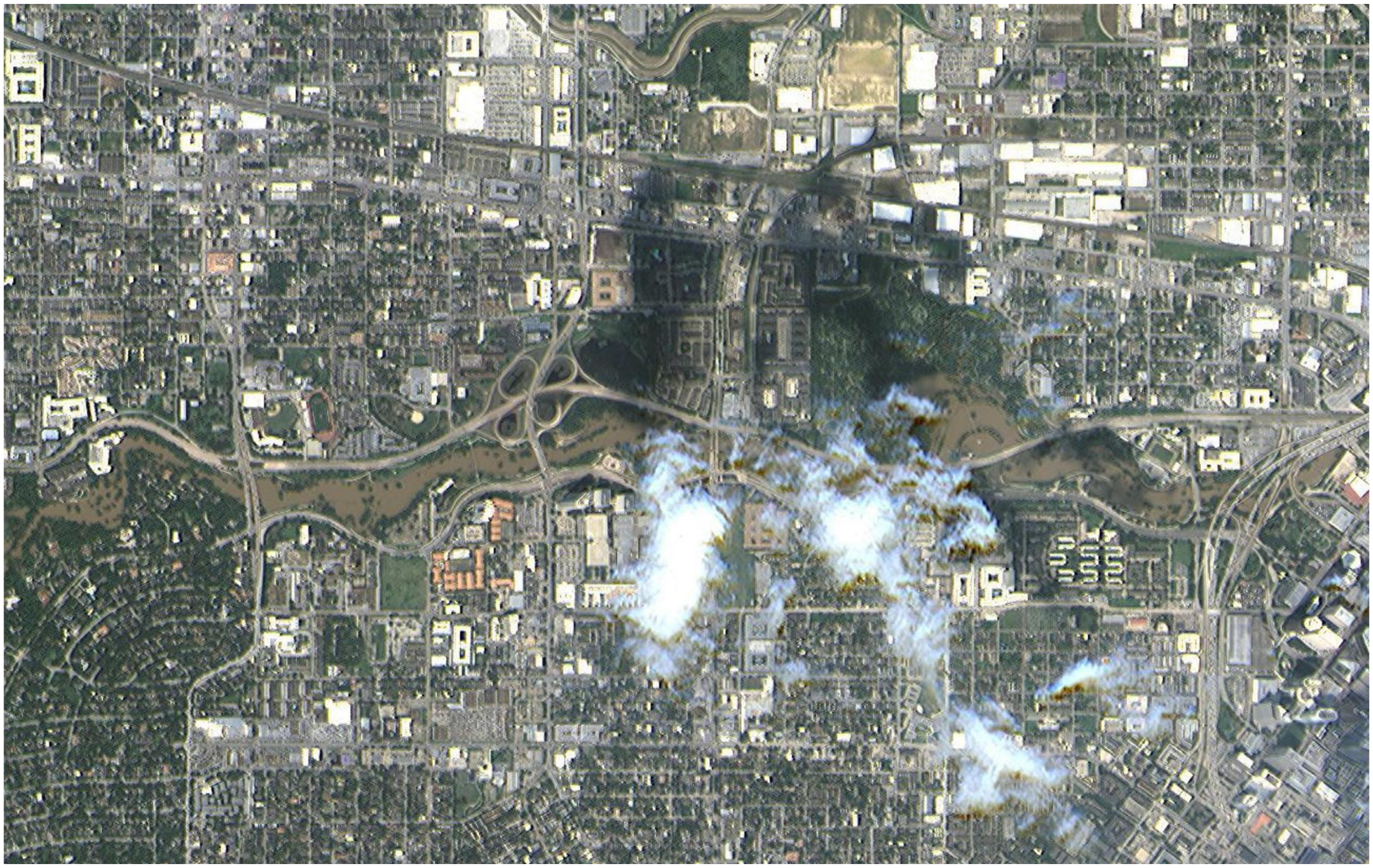

Figure 2. After image of flooded area along Memorial Parkway

Above Figure 1 and Figure 2 shows overall changes over the flooded area in Houston. Even with a zoomed-out image, the flooding aftermath could be detected clearly.

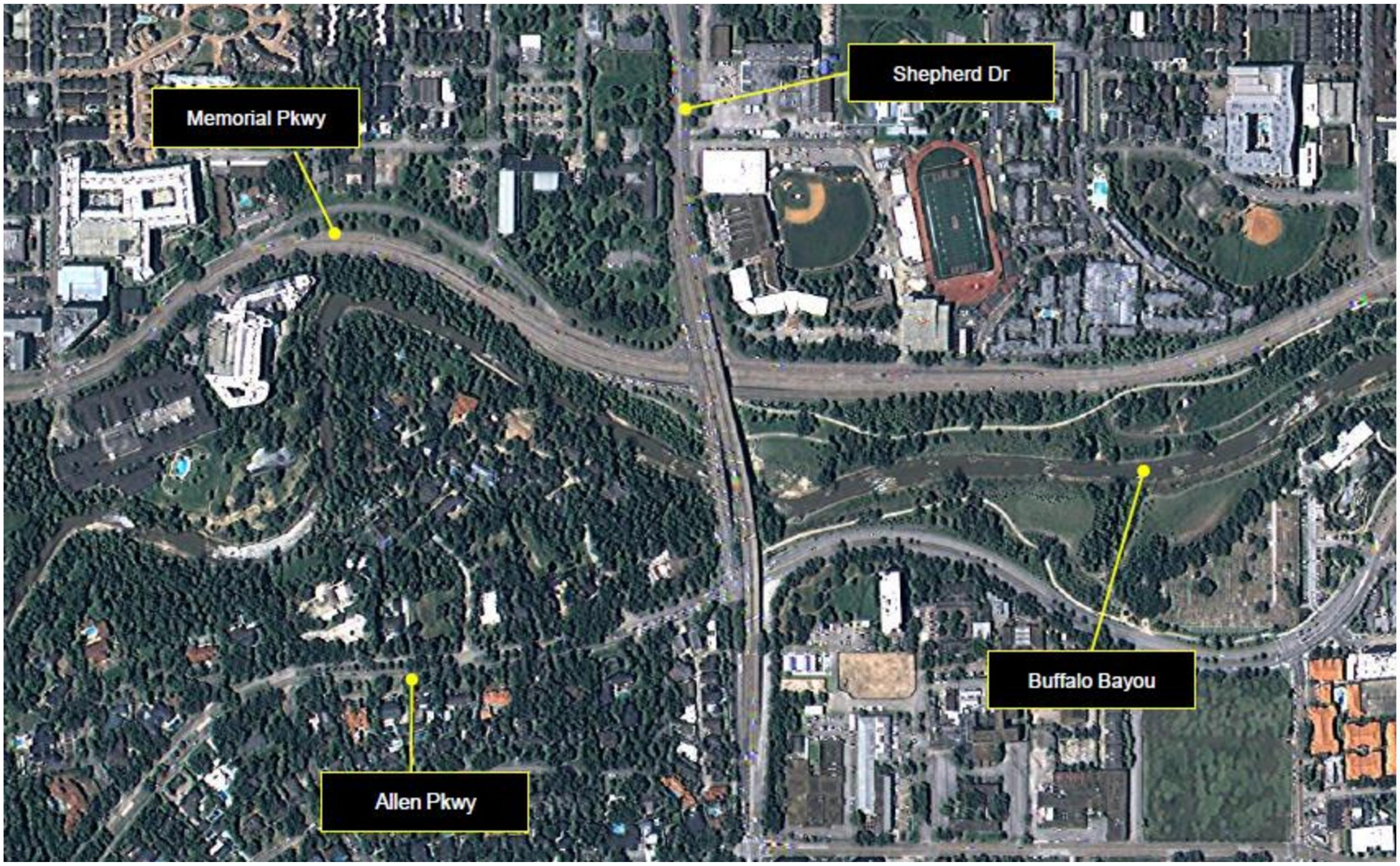

Figure 3. Shepherd Drive over Buffalo Bayou captured on May 4th, 2017 before the flood

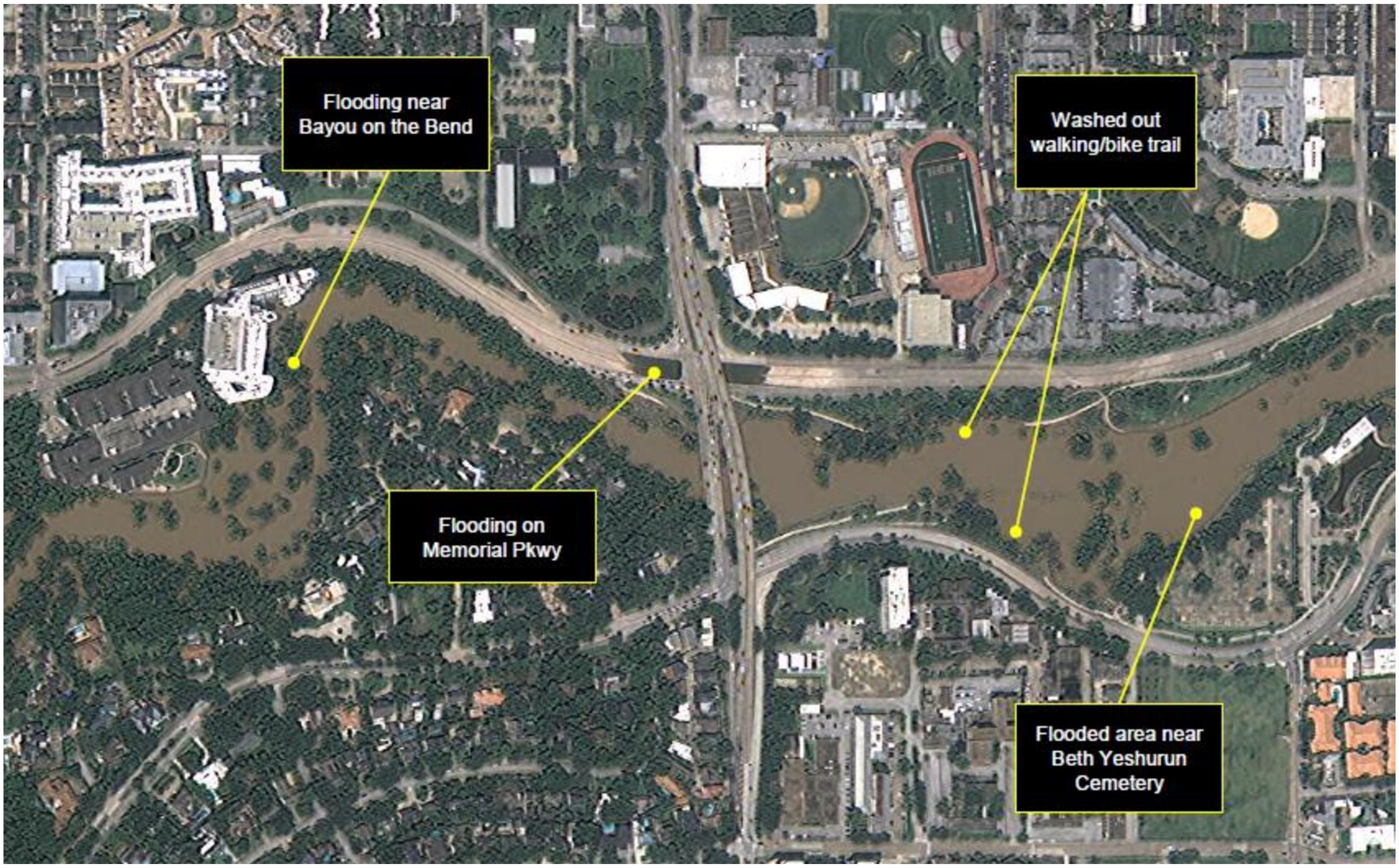

Figure 4. Shepherd Drive over Buffalo Bayou captured on September 1st, 2017 after the flood

Figure 3 and Figure 4 shows zoomed in images over Shepherd Dr. over Buffalo Bayou flooding. Walking and bike trails are washed out, and flooding occurred near Bayou, Memorial Parkway, and Beth Yeshrun Cemetery.

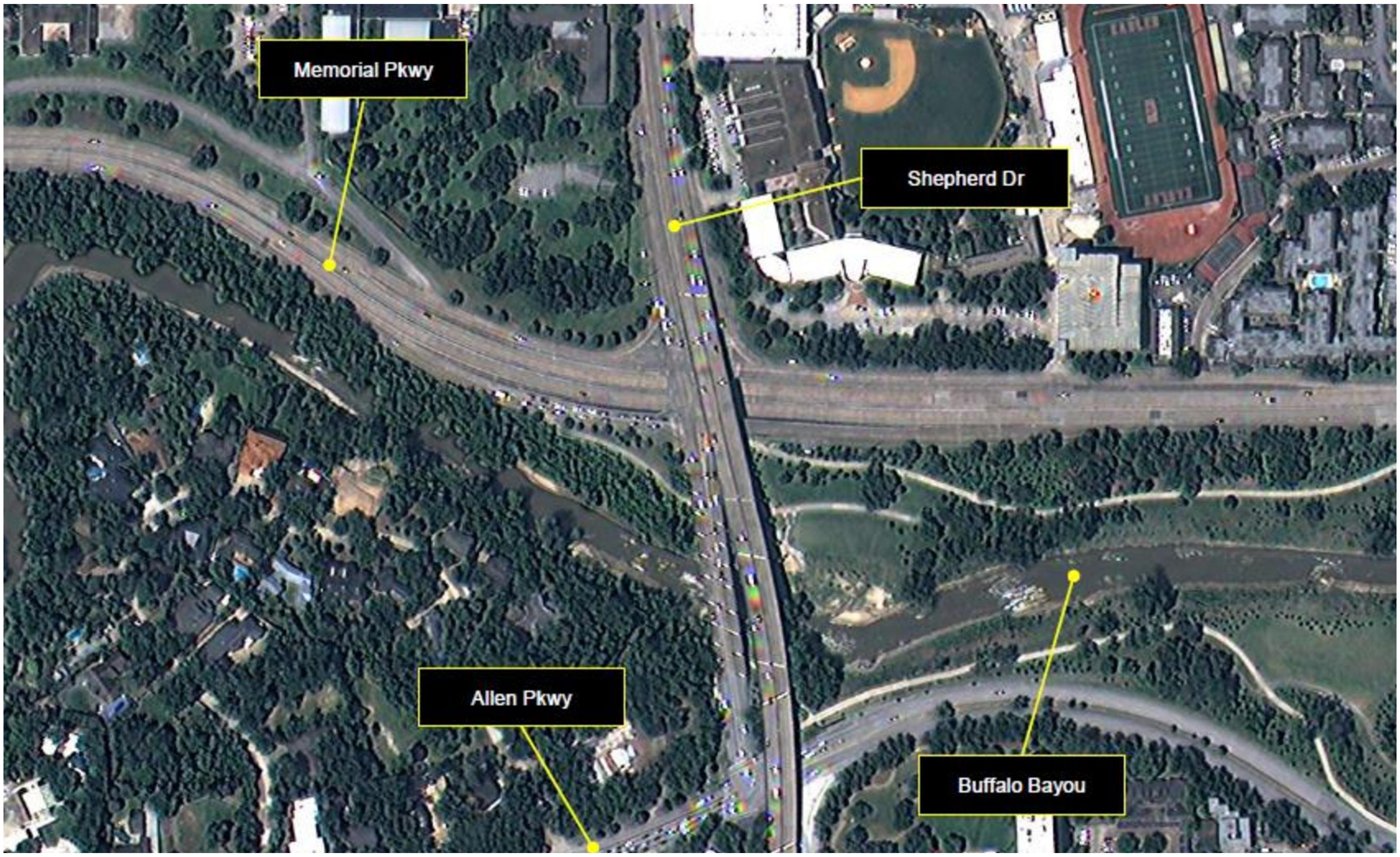

Figure 5. Memorial Parkway captured on May 4th, 2017 before the flood

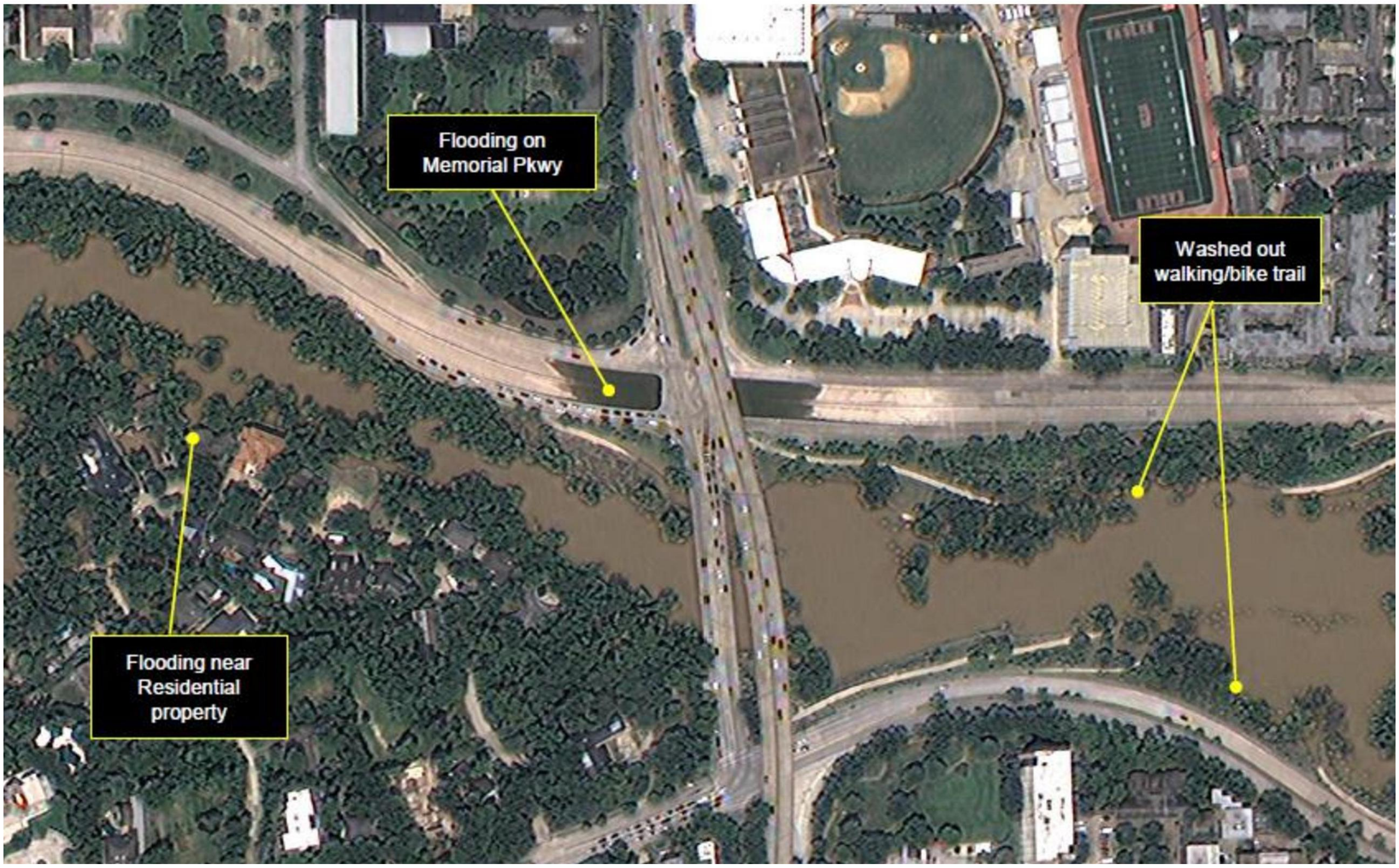

Figure 6. Memorial Parkway captured on September 1st, 2017 after the flood

Comparing Figure 6 to Figure 5, residential property is flooded. Moreover, Memorial Parkway and walking/bike trail are also washed out or flooded as well.

SI Imaging Services (SIIS) is the exclusive worldwide marketing and sales representative of KOMPSAT series KOMPSAT-2, KOMPSAT-3, KOMPSAT-3A and KOMPSAT-5.The KOMPSAT (Korean Multi-Purpose Satellite) program is a part of Korean government's space development program, which aims at providing very high-resolution satellite imagery to national and international remote sensing society. SIIS contributes Remote Sensing and Earth observation industries societies by providing very high resolution optical and SAR images through 100 sales partners worldwide.Customers from industries as well as government and international agencies are using KOMPSAT imagery for their missions and researches and achieve good results in several remote sensing applications such as mapping, agriculture, disaster management, and so on. SIIS started its business as a satellite image and service provider and extended its business to KOMPSAT operation.

AllSource uses satellites, airplanes, drones, social media, weather, news feeds and other real time data services to deliver Geospatial Intelligence produced by advanced software and analysis. These information sources provide Geospatial Intelligence – historical context and data analytic services – based on your needs. Fusing the expertise of a professional network of intelligence trained analysts and artificial intelligence provides AllSource the tools that deliver high priority insight, intelligence and wisdom seamlessly to customers, globally.

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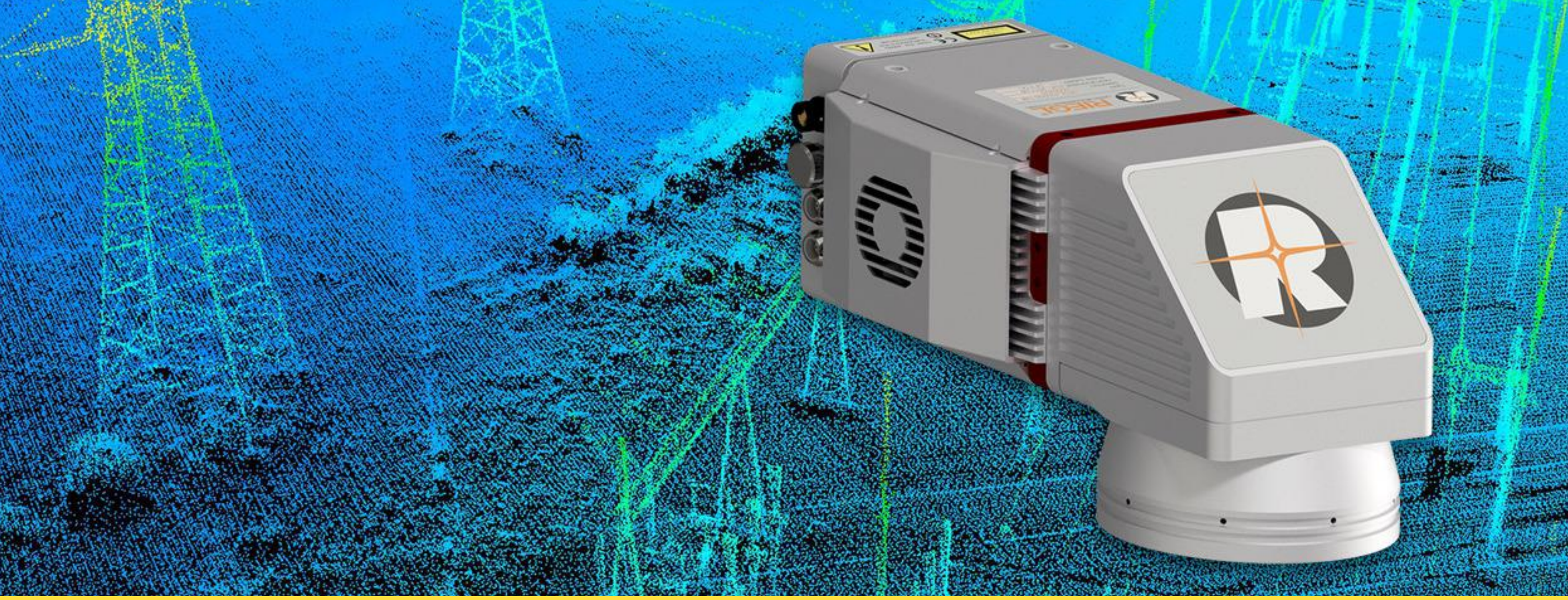
https://en.wikipedia.org/wiki/Hurricane_Harvey



RIEGL’s “Smart Waveform” LiDAR: New Sensors and Systems Offering Unique User Benefits

Image Courtesy: *RIEGL*

Thomas Gaisecker
Senior Manager International Sales,
RIEGL Laser Measurement Systems GmbH,
Austria

PRODUCT WATCH

RIEGL Laser Measurement Systems is an international leading provider of cutting edge technology in airborne, mobile, terrestrial, industrial and unmanned laser scanning solutions. The company maintains an outstanding history of reliability and support to their customers.

RIEGL has been producing LiDAR systems commercially for almost 40 years and focuses on pulsed time-of-flight laser radar technology in multiple wavelengths. *RIEGL*’s core “smart waveform” technologies provide purely digital LiDAR signal processing, unique methodologies for resolving range ambiguities, multiple targets per laser shots, optimum distribution of measurements, calibrated amplitudes and reflectance estimates, as well as the seamless integration and calibration of systems.

RIEGL’s digital signal processing with outstanding performance allows for small objects and wide area DTM to be acquired simultaneously, as well as penetration of dense foliage. It has the capability of radiometric calibration and captures data in real time.

RIEGL instruments operate at different wavelengths to meet the specific requirements of a broad range of applications. The acquired scan data convinces with high ranging accuracy, low range noise, high precision, highest multi-target resolution, and valuable pulse shape information for identification of unwanted points. Classification and filtering assist in providing a solid basis for radiometric measurements.

With the radiometrically calibrated data provided with *RIEGL*'s Waveform-LiDAR technology, the user gains benefits such as improved visual inspection of scans, automatic retrieval of retro-reflecting targets, and straightforward radiometric calibration of data sets. Every laser pulse received provides several attributes in addition to the range measurement information. By using different features and filters provided with the scanner’s software, this information can be used to significantly improve the informative content of point clouds.

Traditionally, *RIEGL* releases their latest LiDAR sensors and systems at INTERGEO. In 2017, four products were highlighted in Berlin; the VZ-2000i long range, very high speed 3D terrestrial laser scanner system, the VQ-880-GH topo-hydrographic airborne laser scanning system, the VQ-780i airborne scanner for wide area mapping, and the miniVUX-1DL "Downward-Looking" LiDAR sensor for unmanned laser scanning.

The *RIEGL* VZ-2000i is a long range, very high speed 3D terrestrial laser scanning system that combines proven user friendliness in the field with fast and high accurate data acquisition (up to 500,000 measurements/second) based on a future-oriented, innovative new processing architecture, and *RIEGL*'s latest waveform processing LiDAR technology.

The processing architecture enables execution of different background tasks such as point cloud registration, geo-referencing, orientation via integrated Inertial Measurement Unit, etc. on-board in parallel to the acquisition of scan data.

RIEGL's unique Waveform-LiDAR technology enables such high speed, long range, high accuracy measurements even in poor visibility and demanding multi-target situations and delivers reliable data even in harsh environments like open-pit mining.

The combination of this latest hardware and *RIEGL*'s software package RiMINING makes the *RIEGL* VZ-2000i an ideal scanner for mining applications. RiMINING is designed to optimize and simplify scan data processing for mining applications. The focus of the software design is on workflow simplification and automation. Applications include topography and mining, surveying in open-pit mining, quarries and dump sites, change detection of excavated areas, fill grade and mass calculation, and extraction of input data for site modeling.

For oceanographic and bathymetric applications such as coastline and shallow water mapping, acquiring base data for flood prevention, measurement for aggradation zones, habitat mapping, surveying for hydraulic engineering, and hydro-archaeological surveying, the *RIEGL* VQ-880-GH was introduced to the market. This fully-integrated topo-bathymetric airborne laser scanning system is offered with an integrated and factory-calibrated high-end GNSS/IMU system and up to two cameras. The design of the system - with a form factor with reduced height optimized for helicopter integrations - allows for flexible application of these components to meet specific requirements.

The system carries out laser range measurements for high resolution surveying of underwater topography with a narrow, visible green laser beam emitted from a powerful pulsed laser source. Subject to water clarity, at this particular wavelength, the laser beam penetrates water, enabling measurement of submerged targets. Two high-resolution digital cameras and an additional infrared laser scanner for smooth detection of the water surface are integrated with the system to supplement the data gained by the green laser scanner.

The new *RIEGL* VQ-780i, a rugged, lightweight, and compact airborne mapping sensor, allows efficient data acquisition at low, mid, and high altitudes, covering a variety of different airborne laser scanning applications from high density to wide area mapping. It is ideally suited for mapping of complex environments,

Figure 1. *RIEGL* VZ-2000i 3D Terrestrial Laser Scanner

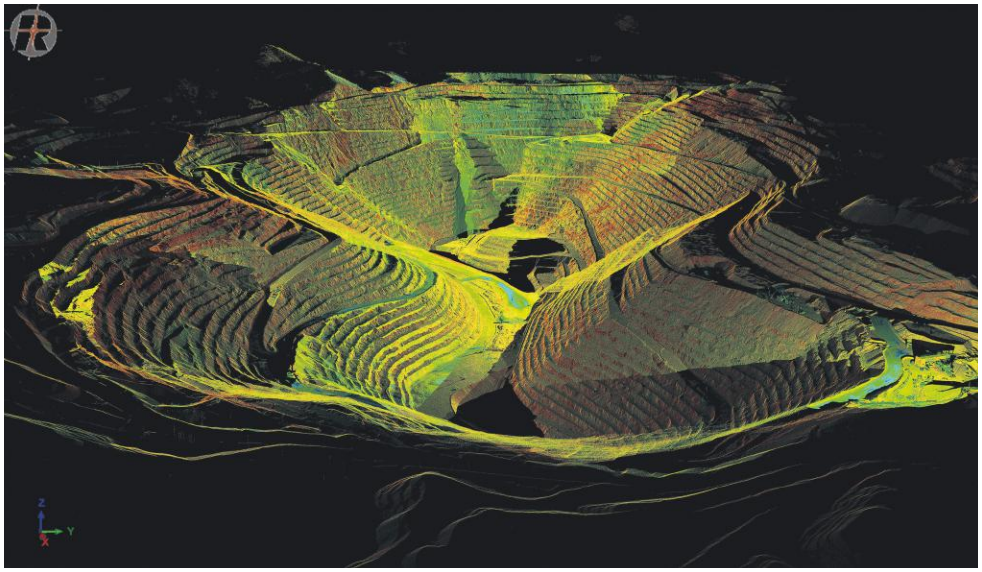


Figure 2. *RIEGL* VZ-2000i Scan Data

glacier and snowfield mapping, city modeling, mapping of lake sides and river banks, and corridor mapping. Based on *RIEGL*'s proven Waveform-LiDAR technology, the system provides clutter-free point clouds with high accuracy, excellent vertical target resolution, calibrated reflectance readings, and pulse shape deviation for unsurpassed information content on each single laser measurement. The sensor is capable of online waveform processing as well as smart and full waveform recording to enable an exploitation of the target features acquired optimally matched to the respective application.

The LiDAR sensor is designed to work with the latest Inertial Navigation (IMU) Systems, flight management systems, and camera options. The scanner's scanning mechanism delivers straight parallel scan lines resulting in a regular point pattern on the ground. With equal spatial sampling frequency along and across track, objects extents are well defined and even small objects may be detected. The wide field of view of 60° and the multiple-time-around measurement capability with up to 25 pulses simultaneously in the air make the VQ-780i perfectly fitted for wide area mapping applications. It provides utmost efficiency in collecting data by enabling scanning operations from high altitudes at high laser pulse repetition rates simultaneously, thus reducing the necessary flight time to a minimum.

Especially developed for corridor mapping applications, the *RIEGL* miniVUX-1DL, a new survey-grade LiDAR sensor, was revealed for the UAV-based market.

The *RIEGL* miniVUX-1DL, available as a standalone LiDAR sensor or as a part of the miniVUX-SYS miniaturized UAV-based laser scanning system, is a sister device to the miniature UAV laser scanner, the *RIEGL* miniVUX-1UAV. The added indicator "DL" means "downward looking" and refers to its special design tailored to meet the needs of corridor mapping tasks such as powerline and pipeline surveillance or for infrastructure inspection as in highway or railway monitoring.

The miniVUX-1DL makes use of *RIEGL*'s unique Waveform-LiDAR technology, allowing echo digitization and online waveform processing. Multi-target resolution is the basis for penetrating even dense foliage. The specific wedge prism scanner construction produces a FOV (Field of View) of ± 23° and the circular scan pattern provides very high point density and excellent point distribution.

These new sensors and systems and their impressive performance capability reflect the highest caliber of innovations that *RIEGL* continuously strives to introduce to the market to provide customers in achieving the best results possible.

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Figure 3. *RIEGL* VQ-880-GH Topo-bathymetric Airborne Laser Scanning System

Figure 4. *RIEGL* VQ-780i Airborne Laser Scanner for High Altitude Wide Area Mapping

Business

Sep.16 - Dec. 15, 2017

Hexagon Acquires Luciad, a Leading Provider of 5D Visualisation and Analysis Solutions

Hexagon AB, has announced the acquisition of Luciad, a Belgian-based software company specialising in the visualisation and analysis of real-time geospatial information. Luciad's visualisation technologies support live connections to dynamic sensor feeds in a 3D environment.

Pix4D is Expanding Globally

Pix4D has added two senior executives to leadership team to strengthen global presence in Europe and North America. Pix4D welcomes Henrik Battke and Thomas Odenwald, joining the company as managing directors of Pix4D GmbH in Berlin and Pix4D, Inc. in San Francisco.

AirMap and Kespry Partner for Safe, Compliant Drone Flights

AirMap and Kespry has announced a partnership that brings AirMap's best-in-class airspace intelligence, including airspace advisories, wind, and weather, to Kespry's leading automated UAV solution. The new integration empowers Kespry's industrial customers to fly with confidence, ensuring that each mission can be flown more safely, more efficiently, and in compliance with relevant airspace conditions and requirements.

Velodyne LiDAR Partners with YellowScan for Integrated LiDAR for UAVs

Velodyne LiDAR Inc., has announced tpartnership with YellowScan to integrate its VLP-16 Puck and VLP-16 Puck LITE LiDAR sensors into YellowScan's Surveyor for a turn-key and reliable LiDAR system for demanding UAV applications. Real-time LiDAR systems for UAVs are leveraged around the world for industrial and scientific applications, including surveying, civil engineering, archeology, and environmental science

Autodesk and Esri Partnering to Advance Infrastructure Planning and Design

Autodesk, Inc. and Esri, Inc. has announced the start of a new relationship to build a bridge between BIM and GIS mapping technologies. Together Autodesk and Esri plan to enable a broad range of industries to gain better context by visualizing data of the man-made world, the environment, citizens and the networks that weave it all together.

UrtheCast and e-GEOS Collaborate to Offer Unique Optical & SAR Products

UrtheCast Corp., and e-GEOS has announced a strategic partnership to offer a unique combination of joint optical and radar sensors with ground stations.The collaboration will allow observation of the Earth day and night, regardless of weather conditions, and is intended to provide a constant asset monitoring service.

Esri Signs Global Enterprise Agreement with Airbus Defence and Space

Esri, has entered into an agreement with the intelligence program line of Airbus Defence and Space. With this new agreement in place, the core GIS will be expanded to meet Airbus's pivotal mission of using creativity and innovation to address the massive economic, social, and environmental challenges our planet faces.

uAvionix, Secures Series B Funding from Airbus Ventures, Playground Global, and Redpoint Ventures

uAvionix Corporation has announced that it has closed a $5 million round of funding led by new investor Airbus Ventures and with continuing participation from existing investors Playground Global and Redpoint Ventures.

Mapbox Acquires Fitness AR to Deepen its Focus on AR

Mapbox, has acquired Fitness AR. Fitness AR will help to build out a team focused on showing the art of creating practical AR applications in key verticals such as travel, weather, fitness, sports and gaming.

GIS & EO

Sep.16 - Dec. 15, 2017

DigitalGlobe Goes All-in on AWS

Amazon Web Services Inc. (AWS), has announced that DigitalGlobe has gone all-in on AWS and is leveraging AWS machine learning technologies to drive deeper insights and improved responsiveness for applications.

AIR Worldwide Expands its Inland Flood Modeling Capabilities to Japan

Catastrophe modeling firm AIR Worldwide has introduced a new inland flood model for Japan along with enhancements to its Japan typhoon model. These models are part of Version 5.1 of AIR's comprehensive catastrophe modeling software platform, Touchstone®.

The Market of Remote Sensing Data & Services will Reach 8.5 Billion Dollar by 2026

According to the 10th edition of the Euroconsult report, the market for remote sensing data and services should reach $ 8.5 billion by 2026, based on current growth trends. Also an alternative model of value-added services (VAS) with a total market potential of $ 15 billion is presented.

Esri Provides Mapping Technology for Students to Assess Hurricane Damage

Esri has provided mapping technology (ArcGIS platform & high-resolution imagery from the Vexcel Corporation) to students so they can use it to identify and assess buildings in Puerto Rico that were damaged by Hurricane Maria.

Remote Sensing Technology Employed in Iran to Identify Archaeological Sites

For the first time in the annal of Iranian technological history, remote sensing techniques have been employed to study and identify archaeological sites and cemeteries in the war zones of Ilam and Kermanshah provinces. The remote sensing archaeological survey in Kermanshah and Ilam, known as the tropical scheme, is aimed at investigating war zones in the two western provinces.

LiDAR

Sep.16 - Dec. 15, 2017

VRMesh V9.5 Available with New Advanced Features for LiDAR Strip Adjustment

This new release provides a simple and fast way for LiDAR strip adjustment with high accuracy. It adds a new feature to separate overlapping LiDAR strips, redesigns and speeds up global registration over 10 times faster, and also allows you to generate a PDF report for viewing the quality of registration.

YellowScan & Quantum Systems Partner to Provide a Cutting Edge VTOL+ LiDAR integrated Solution

YellowScan and Quantum Systems combined their R&D expertise to provide a reliable VTOL+LiDAR solution, able to cover large areas and fly longer (up to 60 minutes). The YellowScan Surveyor LiDAR and the Quantum Tron VTOL (Vertical Take Off and Landing) are both turn-key systems with a "Just press the button" philosophy.

GNSS

Sep.16 - Dec. 15, 2017

Trimble Expands CenterPoint RTX FAST Correction Service in North America and Europe

Trimble has announced the expansion of its CenterPoint® RTX Fast (RTX Fast) correction service in North America and Europe. RTX Fast reduces the convergence time - the duration needed to reach full precision accuracy - by up to 98 percent faster than other satellite-delivered correction services. The service allows customers to realize horizontal positioning accuracy of better than 4 centimeters (1.5 inches) in as fast as one minute.

Japan Successfully Launches 4th Satellite of Quasi-Zenith Satellite System (QZSS)

Mitsubishi Heavy Industries, Ltd. and JAXA successfully launched H-IIA Launch Vehicle No. 36 which encapsulates MICHIBIKI No. 4, Quasi-Zenith Satellite System on Oct. 10, 2017 from the JAXA Tanegashima Space Center.

Hemisphere GNSS Announces Major Enhancements to its Atlas® GNSS Global Correction Service

Hemisphere GNSS has announced a series of major enhancements to its Atlas GNSS Global Correction Service, including Atlas Basic, Atlas AutoSeed, and the addition of global ionospheric modeling to the system. Atlas is a flexible, scalable, and industry-leading GNSS-based global L band correction service and providing correction data for GPS, GLONASS, and BeiDou.

China Successfully Launched Two Navigation Satellites

China has successfully launched two navigation satellites – namely the Beidou-3M1 (Beidou-24) and Beidou-3M2 (Beidou-25) navigation satellite using a Long March-3B/YZ-1 rocket. The satellites are part of a Chinese Beidou (Compass) satellite navigation system and fleet that will expand the system to a global navigation coverage. The satellites are part of satellite constellation of more than 30 Chinese navigation satellite, which is planned to send up over the next three years.

Product Launch

Sep.16 - Dec.15, 2017

GIS & EO

Vexcel Imaging Introduces UltraCam Eagle Mark 3: Wider Swath Width for Increased Efficiency

Vexcel Imaging has introduced the newest model of its widely adopted UltraCam digital aerial camera systems, the UltraCam Eagle Mark 3. The new camera features an unrivaled 26,460 pixels across the flight strip and 17,004 pixels in flight direction, summing up to 449 mega pixel per image. Building on the highly versatile UltraCam Eagle Mark 2 system, the Mark 3 also offers a user-exchangeable lens system and the ability to capture 10 cm GSD at altitudes ranging from 2,000m to 5,250 m above the ground, depending on the installed lens system.

SimActive Introduces New Technology for True Orthos

SimActive Inc., a world-leading developer of photogrammetry software, has announced Correlator3D™ version 7.1 with revolutionary technology for true orthos. Users can now automatically generate enhanced true orthomosaics through a technological breakthrough that significantly minimizes artifacts.

LiDAR

GeoSLAM Launches Time & Cost Saving 3D Mobile Laser Scanners

The ZEB-REVO RT is the next generation of the hugely popular ZEB-REVO – GeoSLAM's lightweight, handheld laser scanner which allows the rapid and simple mapping of complex, indoor and multi-level spaces. The ZEB-REVO RT utilizes WiFi technology to seamlessly connect the scanner to a mobile phone or tablet, allowing for real time data visualization as you walk and scan. The simultaneous scanning and processing of 3D data removes any need for post-processing – effectively slashing project survey times in half.

Orbit GT Releases 3D Mapping Feature Extraction Standard v18

Orbit GT has announced the release of second product from the Feature Extraction portfolio. The version 18 bundles all the expertise and technology to support the various types of 3D mapping techniques, all users of Mobile Mapping, Oblique Mapping, UAS Mapping, Indoor and Terrestrial Mapping, can now use a single integrated tool for managing and exploiting all of their 3D data. This is a true revolution in the 3D Mapping business, providing dramatic improvements in workflow efficiency and overall project management.

GNSS & Surveying

Sokkia Introduces New Radio Modem for GCX Receiver Line

Sokkia has announced a new radio modem designed to offer advanced radio connectivity with GNSS receivers — the R4S-BT. The UHF radio solution provides an external option for use with the Sokkia GCX receiver line. The R4S-BT makes the GCX GNSS receiver into an even more scalable and modular solution. The UHF multichannel radio modem has a tuning range of up to 70 MHz.

Sokkia Introduces New Manual Total Station with Sophisticated Features

Sokkia has recently introduced a new total station designed to provide advanced integrated communications technology and a powerful EDM - the iM-100. he iM-100 features a best-in-class accuracy up to 5,000 m with a prism and up to 800 m in reflectorless mode. The iM-100 features dual-axis compensation designed to ensure stable measurements even on rough terrain. The compensator automatically corrects both horizontal and vertical angles and allows for more accurate instrument setups and measurements.

Topcon Announces New Web-Based Service for Mass Data Processing Software

Topcon Positioning Group has announced a new web-based service for integration with the MAGNET® Collage desktop mass data processing software - MAGNET Collage Web. The web-based service is designed to simplify collaboration and sharing of 3D point cloud data. MAGNET Collage Web offers a sleek platform, accessible through a web browser, that integrates with the MAGNET Collage Office version to allow professionals to publish and share their mass data maps in a user-friendly and intuitive 3D web-based environment. MAGNET Collage is designed to offer a "single environment" solution for professionals processing and publishing data from different surveying instruments.

Mobile Apps

TerraGo Edge Version 4.2 Enhances Field User Experience and Mobile Mapping

TerraGo has announced the availability of TerraGo Edge Version 4.2 and any app created with the TerraGo Magic zero-code app platform includes enhancements to the user experience that accelerate mobile field data collection and asset management.

Avenza Maps iOS App Launches in the GEOINT App Store

Avenza Maps, including unlimited access to the Avenza Map Store's extensive catalogue of digital maps, is available for iOS devices to all DoD and IC personnel by creating a GEOINT account using existing federal credentials, such as Common Access Card (CAC) or Personal Identity Verification (PIV). Once registered, the Avenza Maps app can be downloaded without cost to their mobile device.

New Data Resource

New Tool Allows Users to Explore Mountains Worldwide

The Global Mountain Explorer can help a variety of users – from hikers planning their next adventure, to scientists, resource managers and policy makers seeking information that is often sparse in these prominent yet often understudied landscapes. The USGS developed the Global Mountain Explorer, in partnership with ESRI, and three organizations at the University of Bern in Switzerland.

Geo Events

15-19 January, 2018
Geospatial World Forum
Hyderabad, India
https://geospatialworldforum.org

05-07 February, 2018
International LiDAR Mapping Forum
Denver, CO, USA
https://www.lidarmap.org/

18-21 March, 2018
Gi4DM - 2018
Istanbul, Turkey
http://www.gi4dm2018.org

20-21 March, 2018
Esri Federal GIS Conference
Washington, D.C., USA
http://www.esri.com/events/federal

24 - 25 April, 2018
12th International Navigation Forum
Moscow, Russia
http://glonass-forum.com

24 - 27 April, 2018
Navitech - 2018
Moscow, Russia
http://www.navitech-expo.ru/

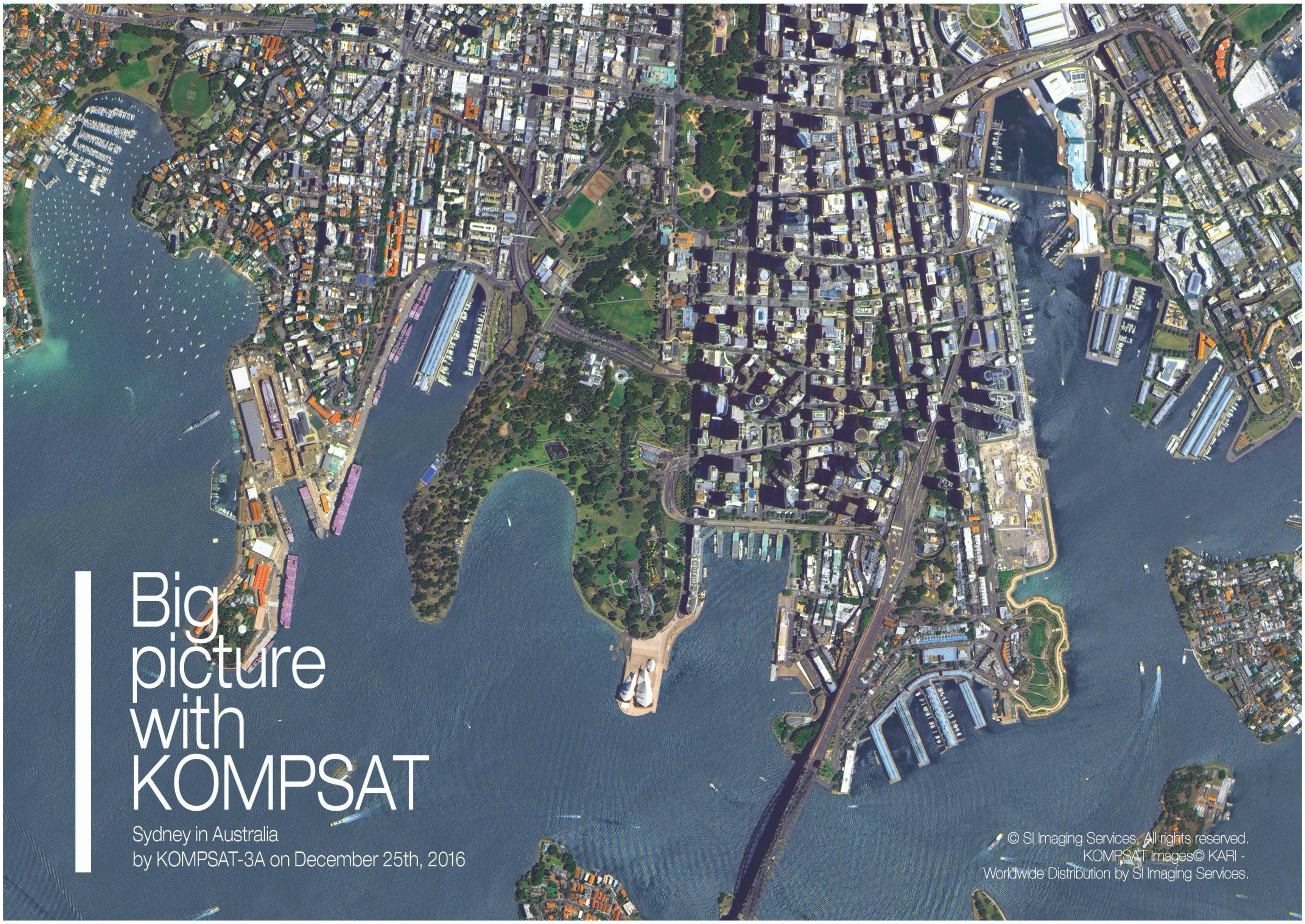
14 - 16 May, 2018
FOSS4G North America 2018
St. Louis, MO, USA
https://2018.foss4g-na.org

22 - 23 May, 2018
GEO Business 2018
London, England, UK
http://geobusinessshow.com

SIIS
SI Imaging Services

Satellite imagery

40 cm resolution product
We can zoom in to look at ships docked in Sydney.



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