VOLUME 16 ISSUE 3

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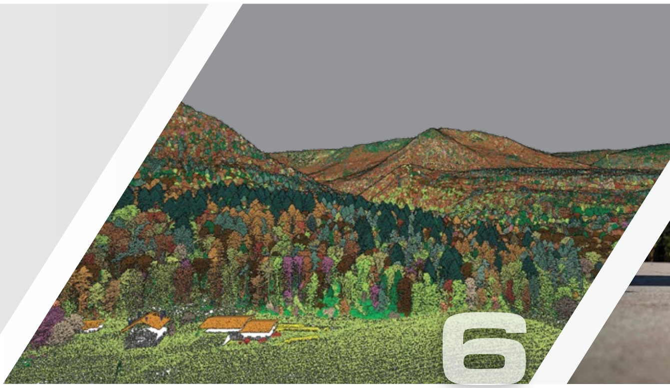

IN THIS ISSUE

DEPARTMENT

On the cover: A virtual representation of the forest in Neuchâtel, Switzerland. Tree species identification results generated in 2D were reprojected onto a lidar point cloud to enable the image shown. For more, visit: https://sitn.ne.ch/lidar

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ALLEN E. CHEVES

Decisions That Matter

This month's edition offers a broad look at how lidar, positioning, and GeoAI integrations continue to evolve. This evolution is not simply the result of better technology, but of the ways those tools are being applied to increasingly complex real-world problems.

We begin once more in Neuchâtel, Switzerland, where Marc Riedo, Matthew Parkan and Corentin Junod explore the use of high-density aerial lidar and deep learning to better understand forest structure. Their work demonstrates how detailed point clouds can support species classification, resource assessment and increasingly automated forest inventories.

On page 20, Kevin Andrews takes us beyond the traditional measure of positioning performance: accuracy. His article examines how sensor fusion is helping systems remain reliable in urban environments, rail tunnels and active airport airspace. The common theme is resilience, with positioning technology continuing to perform when GNSS alone is no longer enough.

In Florida, Al Karlin, Nicole Hewitt and Madison Trowbridge revisit Kings Bay and Crystal River through a decade of topo-bathymetric lidar surveys. Beginning on page 26, their comparison illustrates both the value of repeated elevation mapping and the care required when interpreting change through time.

On page 34, Ada Perello is back with installment four of our "Elevations for the Nations" series, addressing lidar use in Czechia, Norway, Slovakia, Slovenia and Sweden. These profiles reveal the varied approaches to national lidar programs across Europe and explore the prospects for a broader pan-European elevation dataset.

Immediately afterwards, on page 41, David Jones of McKim & Creed brings the focus back to the United States with a look at surveying's role in Western North Carolina following Hurricane Helene. As existing maps and records became outdated, surveyors provided the accurate field information needed to begin rebuilding.

Closing out this edition, a Q&A with Chanlee Vincent of NV5 examines the gap between experimentation and operational adoption in GeoAI, including how agentic AI may help integrate lidar, imagery, GIS and enterprise systems into more connected workflows.

Taken together, these stories reflect an industry moving far beyond data collection alone. The real value increasingly lies in resilience, interpretation, integration and the ability to turn complex geospatial information into decisions that matter.

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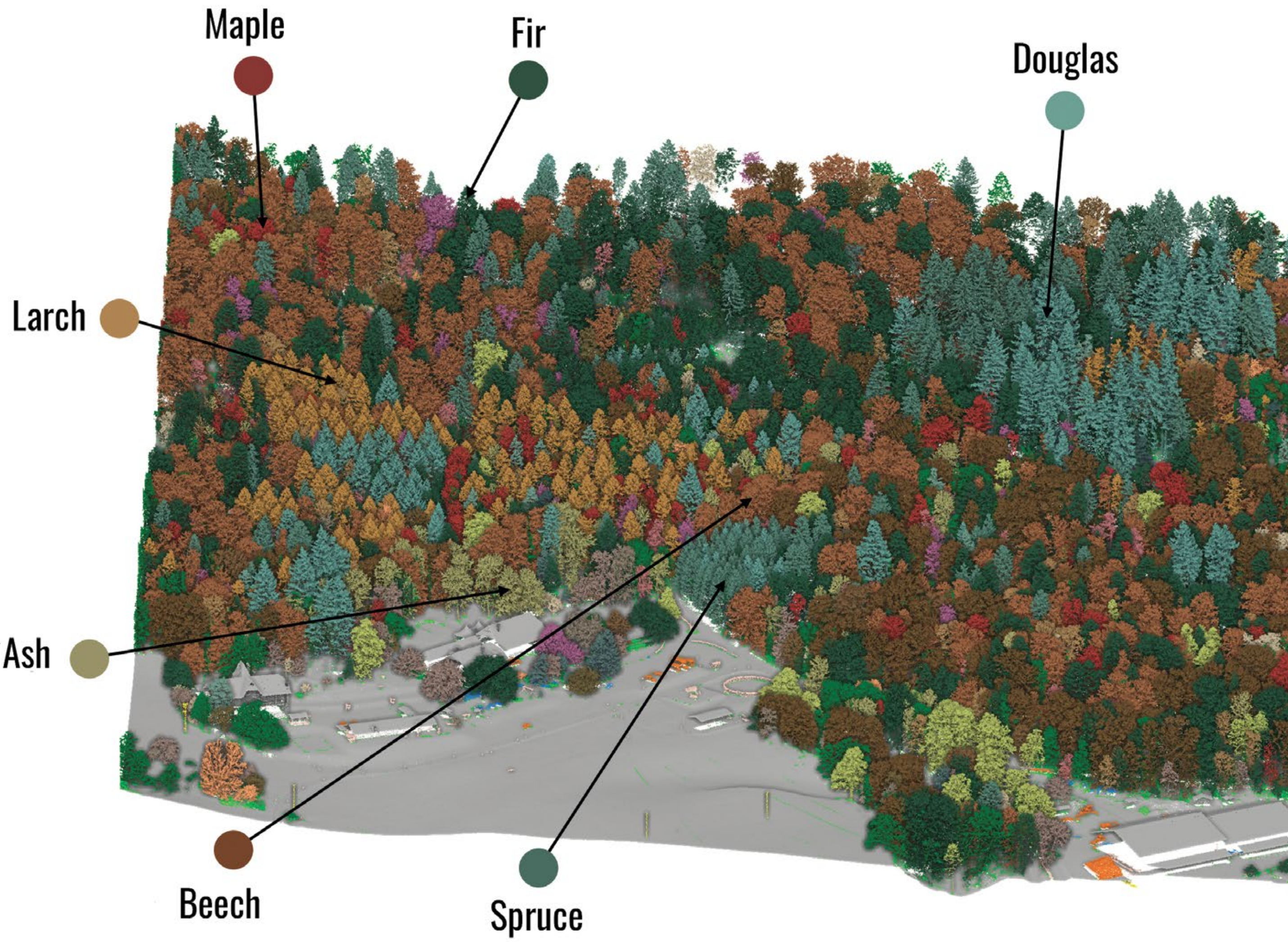
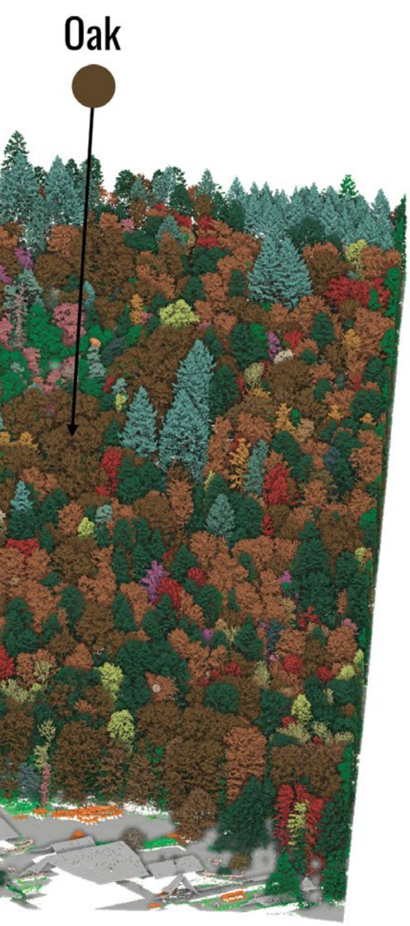
A Slice of Swiss Trees

Individual-tree forest mapping with high-density aerial lidar and deep learning in Neuchâtel, Switzerland



BY MARC **RIEDO,** MATTHEW **PARKAN,** CORENTIN **JUNOD**

By combining high-density aerial lidar and deep learning, it becomes possible to reveal the forests of Neuchâtel with an unprecedented level of detail. By leveraging point clouds with over 100 points/m² (ppsm) and very high-resolution derived models, the Neuchâtel government GIS center (SITN) offers products that foresters can use directly, ranging from simple raster products, such as the canopy height model, to the most advanced, derived directly from the 3D point cloud. These methods enable tree crown segmentation, followed by the classification of 20 major tree species using aerial lidar signatures that combine geometry and intensity, achieving an overall classification accuracy of approximately 80%, and over 90% for conifers. This innovation offers a comprehensive, detailed, and dynamic view of Neuchâtel's forests, paving the way for nationwide automated inventories, precise estimates of forest resources, and better understanding and anticipation of climate change impacts on an ecosystem under significant pressure.



Source: SITN LiDAR point cloud: Marc Riedo

Figure 1: RIEGL VQ-1560 II-S lidar sensor from Swiss Flight Services used for the 2022 and 2025 surveys.

Introduction

For the past 25 years, the Neuchâtel government GIS center (SITN) has been using lidar surveys to map forests, in close collaboration with the canton's forestry service (SFFN). Lidar data provides a detailed, objective 3D view of forest structure. This revolutionary technology, available for civilian applications since the mid-1990s, continues to improve and become more widely accessible. While the first sensors used in the early 2000s generated 20,000 measurements per second at a density of 1 ppsm, current sensors operate at frequencies of up to 4 million pulses per second, generating point clouds with a density of over 100 ppsm at a flight altitude of 1,000 m, making it possible to cover a Swiss canton in just a few days. Many countries have created, or are in the process of creating, national lidar coverage (France, Spain, Portugal, Germany, Italy, US, etc.). Switzerland, a pioneer in this field, is currently conducting its third national survey with Swisstopo's swissSURFACE3D product, updated every six years. Several Swiss cantons supplement these surveys to achieve

2001 survey: 1 ppsm (~100 points per tree); 2016 survey: 30 ppsm (~3,000 points per tree); 2025 survey: 100 ppsm (from ~10,000 to ~30,000 points per tree, ~1,500 points per trunk)

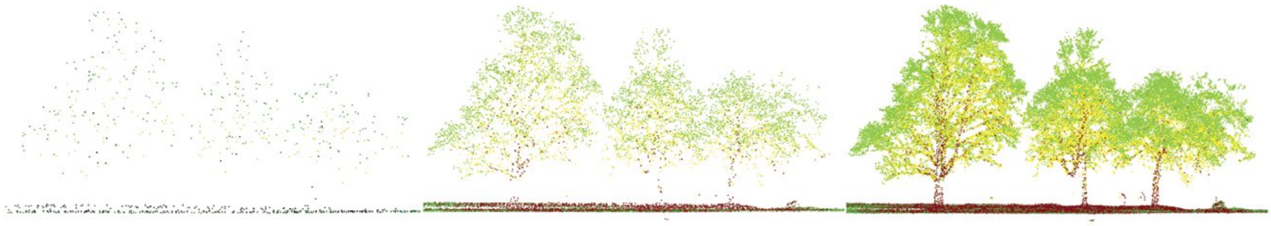


Figure 2: Changes in data density as lidar sensors improve.

higher point density or more frequent updates. This is the case in Neuchâtel, which aims for a complete survey every three years. SITN currently has six aerial lidar surveys of its territory: 2001 (1 ppsm), 2010 (7 ppsm), 2016 (30 ppsm), 2019 (16 ppsm), 2022 (100 ppsm) and 2025 (100 ppsm). **Figure 1** is an illustration of one of the sensors used. In the last two surveys, the density rises to an average of 250 ppsm above forest counting all returns, corresponding to ~10,000 to ~30,000 points per tree. This high density makes it possible to extract detailed information for each individual tree.

A three-year update cycle enables regular monitoring of forests, which are subject to very high stresses related to climate change: drought, heat waves, and extreme weather events (storm in La Chaux-de-Fonds in 2023 with over 30,000 trees destroyed; late snowstorm in Valais in April 2025 with over 100,000 trees destroyed); dieback (beech, spruce). **Figure 2** shows the variation in data density and the ability of the data to describe the canopy for each individual tree. It illustrates the difference in the amount of information that can be extracted depending on the density of the point clouds.

SITN has recently developed deep learning methods to produce high-resolution forest maps across Neuchâtel (30,000 hectares), identifying approximately 10 million trees and classifying them into 20 species. Beyond tree species identification — a crucial indicator for understanding how forests adapt to climate change — the ultimate goal is to determine or estimate as many dendrometric variables as possible: height, crown, tree diameter, trunk diameter, standing timber volume and stand structure.

This innovation builds on many years of experience, combining the expertise of SFFN, SITN engineers, and close collaboration with the research community, particularly EPFL (two PhD theses: G. Gachet in 2009 and M. Parkan in 2018).

Lidar products and use cases for forestry

Several products derived from lidar surveys, such as digital terrain models (DTMs), digital surface models (DSMs), canopy height models (CHMs) and canopy evolution models (ΔCHMs), have become tools used daily by forestry professionals (**Figure 3**). These raster products (images, regular grids) are easy to use and simple to generate, and do not necessarily require very high lidar density, although their quality improves as density increases. SITN currently works with cantonal DTMs and DSMs with a high resolution of 10 cm, and CHMs and ΔCHMs with a resolution of 20 cm. Lower resolutions can also be used,

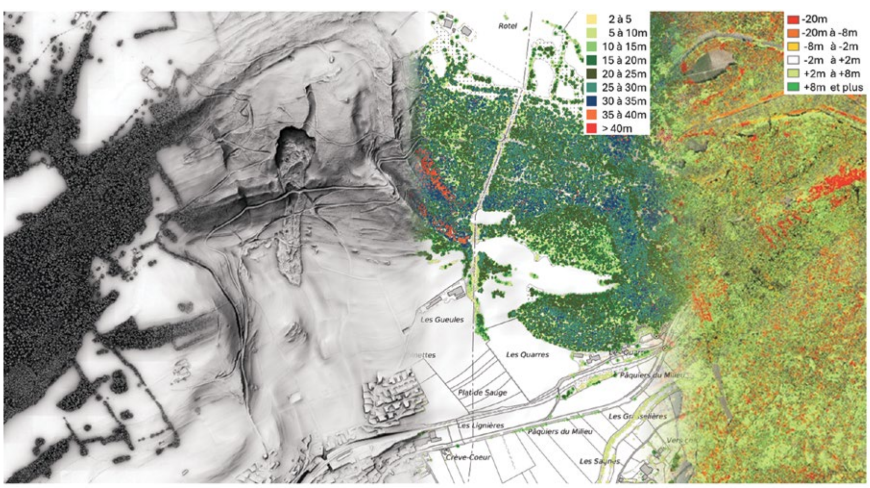


Figure 3: From left to right — DSM, DTM, CHM, and canopy change model (ΔCHM).

Product	Usage
DSM	Precise mapping of forest edges Mapping of the overall structure of forest cover Locating trees for forest inventories
DTM	Detailed and accurate terrain model beneath the forest canopy: slope, aspect, erosion Design of forest roads and detection of skid trails Detection of geological hazards, landslides, and rockfalls
CHM	Description of the forest's vertical structure Determination of the average stand height Determination of the height of isolated or emergent trees Base map for implementing thinning plans Continuity of forest cover and clearings Estimation of standing timber volume Basis for tree classification Biomass estimation Forest fire intensity potential
ΔCHM	Detection of felled trees and identification of canopy differences Identification of affected areas and estimation of volumes following a storm or fire Estimation of wood growth at tree, management-unit, and cantonal levels

Table 1: Some uses of forest management products.

depending on the application. **Table 1** lists some applications of these products.

- The DSM is interpolated from the point cloud using the spike-free DSM algorithm, and the shading is calculated using ambient occlusion, which conveys 3D information better than directional shading.
- The DTM reveals numerous details (skid trails) beneath the canopy thanks to the high point density and the canopy-penetrating capability of lidar. DTM shading is calculated using an algorithm from the Relief Visualization Toolbox (Archéo Blend).
- The SITN CHM is calculated directly from the height-normalized point cloud (terrain elevation removed). It can also be calculated by subtracting the DTM from the DSM.
- The CHM evolution is calculated by differencing the CHMs from different surveys.

Tree detection

Recent innovations at SITN have made it possible to segment the point cloud by tree and classify tree species of Neuchâtel's forests. To achieve this objective, the following challenges had to be addressed:

- Acquiring high-density lidar data (>100 ppsm)
- Managing large volumes of data, over 100 billion measurements in the lidar point cloud, i.e., several terabytes (4 TB in LAS and 1 TB in LAZ COPC)
- Generating derived products: classification of lidar points, calculation of DSM, DTM, and CHMs
- Developing a tree crown segmentation algorithm, i.e., delineating the footprint of each tree
- Developing an algorithm to identify tree species

Segmentation of tree crowns

To characterize forests at the individual tree level, the first step is to separate the trees from one another. This process is called instance segmentation, from the Latin word segmentum ("piece" or "part"), itself derived from secare ("to cut").

This segmentation problem, which can be applied to various types of data (2D/3D raster, 3D point cloud), has been extensively studied in forest remote sensing. It is particularly complex in the irregular, dense, and mixed forests found in Neuchâtel. It has not been fully resolved to date, although considerable progress has been made in recent years thanks to the rise of methods based on deep neural networks (deep learning), the availability of high-resolution training data, and access to significant computational power, particularly through the use of high-end Graphics Processing Units (GPUs). The most recent state-of-the-art segmentation methods actually produce excellent results by working directly on 3D data. However, they remain rarely implemented at regional or national scales, mainly because they place high demands on computational resources and data quality (resolution).

The segmentation method developed for this project does not aim to achieve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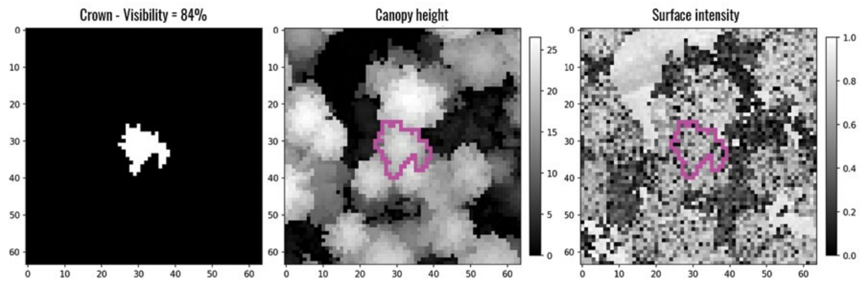

Figure 4: On the left, the footprint of a tree canopy (in white) that we are trying to predict (it is also overlaid in pink on the other two images for illustrative purposes). In the center, a section of the canopy height model. On the right, a section of the lidar echo intensity model.

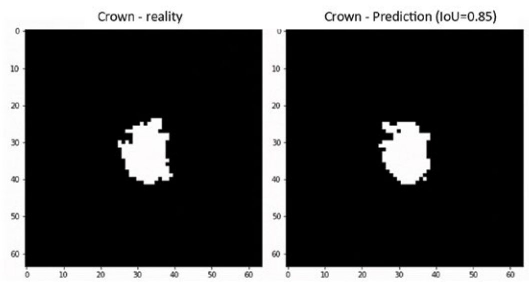

Figure 5: Example of a comparison between an actual tree crown (manually measured reference) on the left and the prediction from the segmentation model on the right. The similarity score here is 85%.

state-of-the-art results, but rather to provide a generalizable solution, suited to operational implementation at a regional scale. It uses a deep neural network trained to predict tree crown boundaries based on canopy height and the intensity of lidar echoes (**Figure 4**). The canopy height model provides information on the shape of the crown, while the lidar echo intensity model is related to its reflectance at the laser's operating wavelength (near infrared, 1064 nm) and is particularly useful for distinguishing between evergreen and deciduous trees in leaf-off surveys. These two variables provide both geometric and radiometric discrimination that helps distinguish adjacent crowns. An initial training phase is used to optimize the model parameters by repeatedly comparing thousands of manually delineated reference crowns with the model outputs. Agreement between the reference and predicted crown footprints is quantified using a shape-overlap score (**Figure 5**), with values approaching 100% indicating a close match. An automated optimization procedure then iteratively adjusts the parameters until improvements in the score level off across the training dataset. In a second phase, the optimized model is evaluated on a test dataset (i.e. tree crowns that were not used for training but have known reference footprints). This allows its performance on unknown data to be estimated. The results of this phase indicate good generalization performance, with similarity scores generally ranging between 80% and 90%. However, there are cases of poorly segmented forest patches, particularly in deciduous forest areas where the canopy structure is homogeneous and where individual trees are difficult to distinguish, even to the human eye.

Finally, the model is applied to the entire dataset to produce a segmentation map at the canton level (see excerpt in **Figure 6**). To do this, it is run iteratively to small analysis windows centered on candidate locations, starting with the tallest trees, until the entire territory is covered. The resulting 2D segmentation, draped over the point cloud, is shown in **Figure 7**.

In other words, the canopy is dissected, tree by tree, from the highest to the smallest, like pieces of a puzzle. For practical reasons, the canton is divided into 500 m by 500 m tiles with overlap. A notable limitation of this method is that it uses only the information visible in the upper canopy. Trees located in the

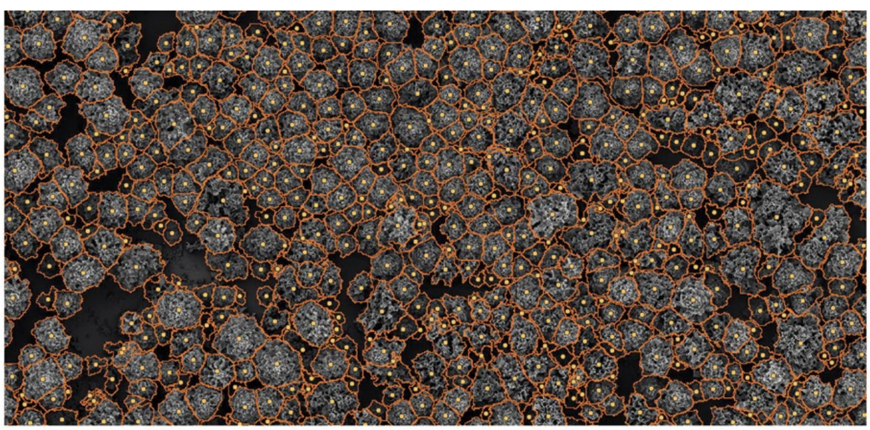

Figure 6: Segmentation results showing the crown footprints (in orange) and their centroids (yellow dots).

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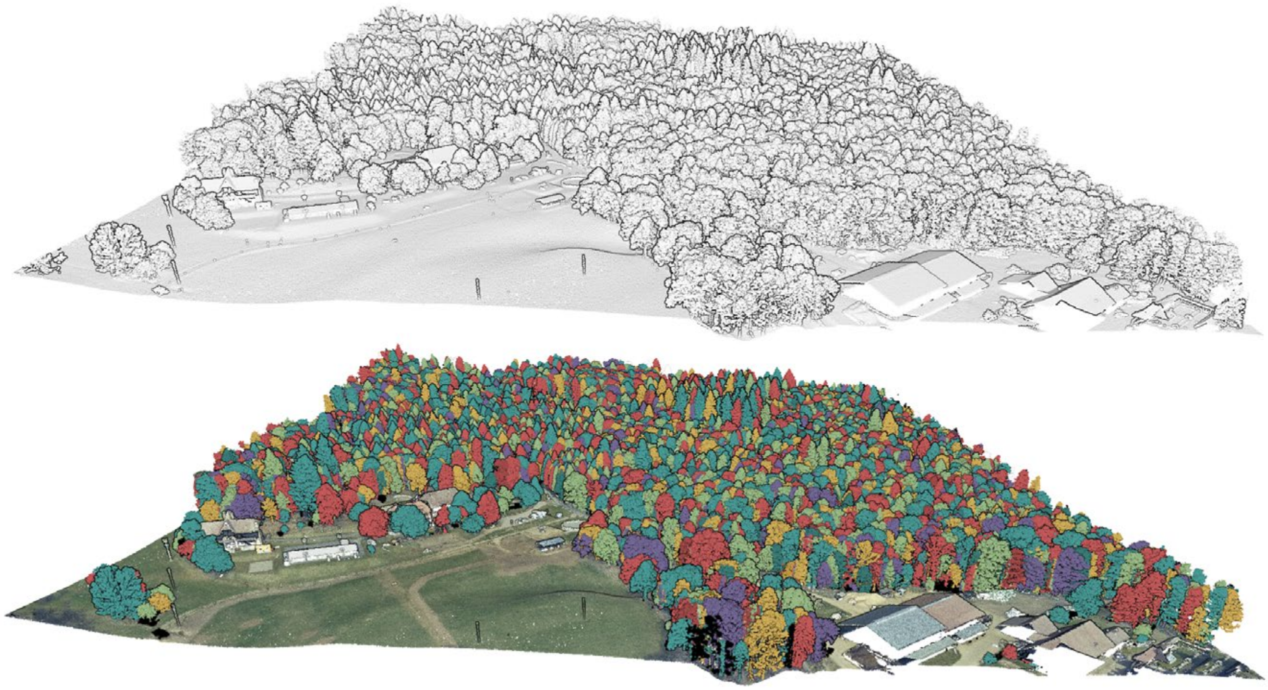


Figure 7: Raw point cloud (top) and the same cloud colored by upper-canopy segmentation (bottom), with points grouped by tree crown.

understory are therefore only partially segmented or not detected. There is room for improvement, particularly with the addition of training data to better represent the actual variability of tree crowns and thus increase the robustness of the method.

Classification of tree species

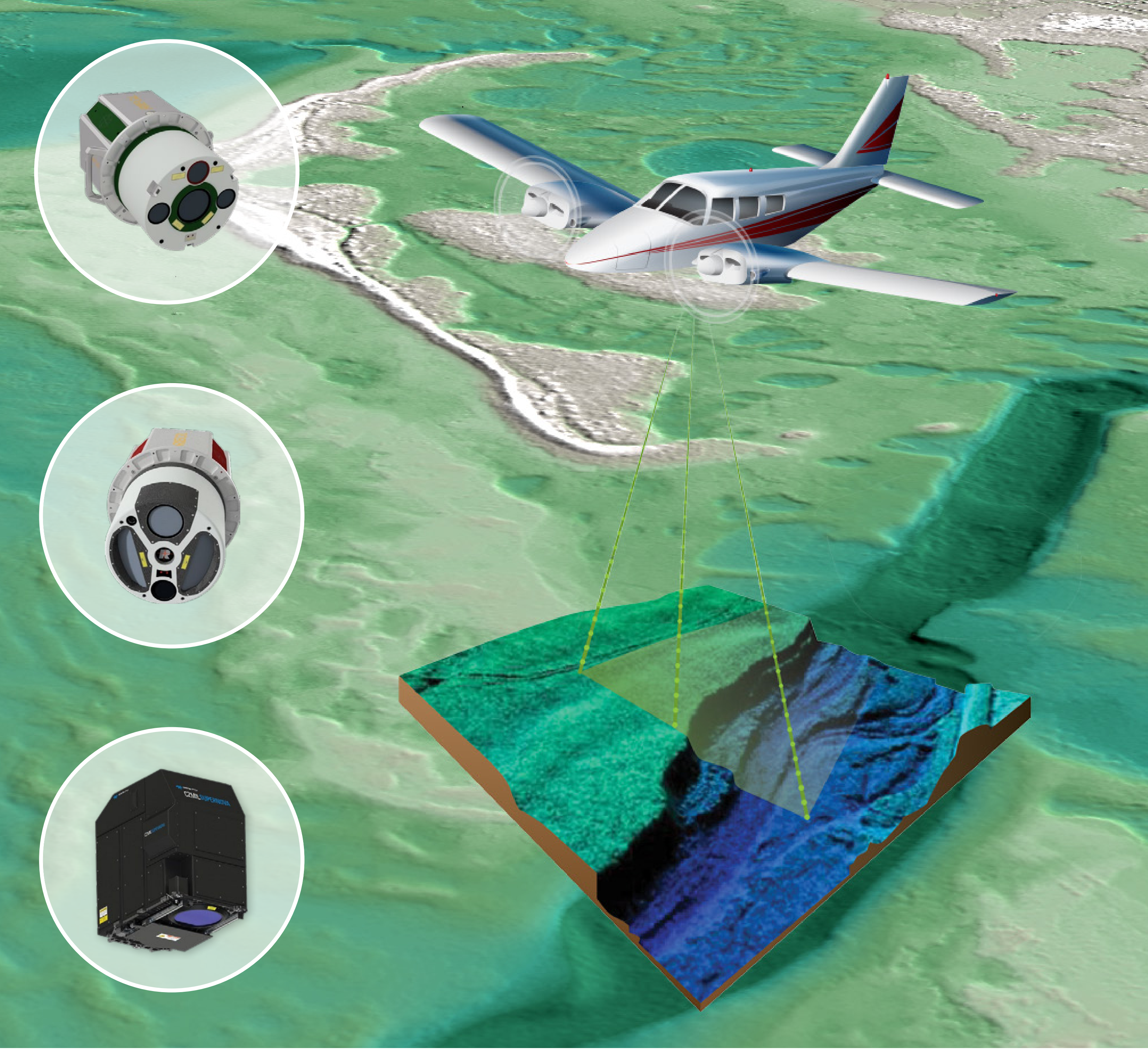
Tree species are also classified using an artificial intelligence algorithm. Instead of working directly with the lidar point cloud, which requires significant computing power, the algorithm uses two-dimensional profiles. For each tree surveyed, the algorithm extracts three vertical cross-sections and an aerial view from the point cloud. The points extracted are then converted into two images, one showing the density of lidar points, the other their return intensity. This intensity is a key parameter for classification. An example for two trees is provided in **Figure 8**.

Since the lidar beam operates at an infrared wavelength (1064 nm), it is partially absorbed by vegetation, to varying degrees depending on the plant type. Subtle changes in the laser's return intensity then provide valuable information about the species of the tree observed. Once the cross-sections have been extracted from the point cloud, they serve as input to the artificial intelligence model tasked with classifying tree species. This uses a neural network (deep learning) that must first be trained.

During this phase, the model learns to distinguish between tree species using annotated data, i.e. data for which the true species is known. Whenever the model makes a mistake, its parameters are adjusted to improve its performance. By repeating this process a very large number of times, on a large dataset, the result is a trained model that classifies tree species as accurately as the data allow.

The model was developed and trained entirely in-house by the SITN team. The data used for training includes more than 30,000 trees surveyed by the Neuchâtel Forestry Service and the Lyss Forestry Competence Center, plus several thousand trees provided by the cities of La Chaux-de-Fonds and Neuchâtel, and by the forest inventory of the canton of Zug.

With nearly two million parameters, the model is trained in about ten hours on a desktop computer fitted with a GPU suited to AI workloads, which allows the model to be adjusted quickly and several specialized versions to be created. When trained on the 20 most common tree species in the canton of Neuchâtel, using trees at least 8 m tall, the model correctly classifies over



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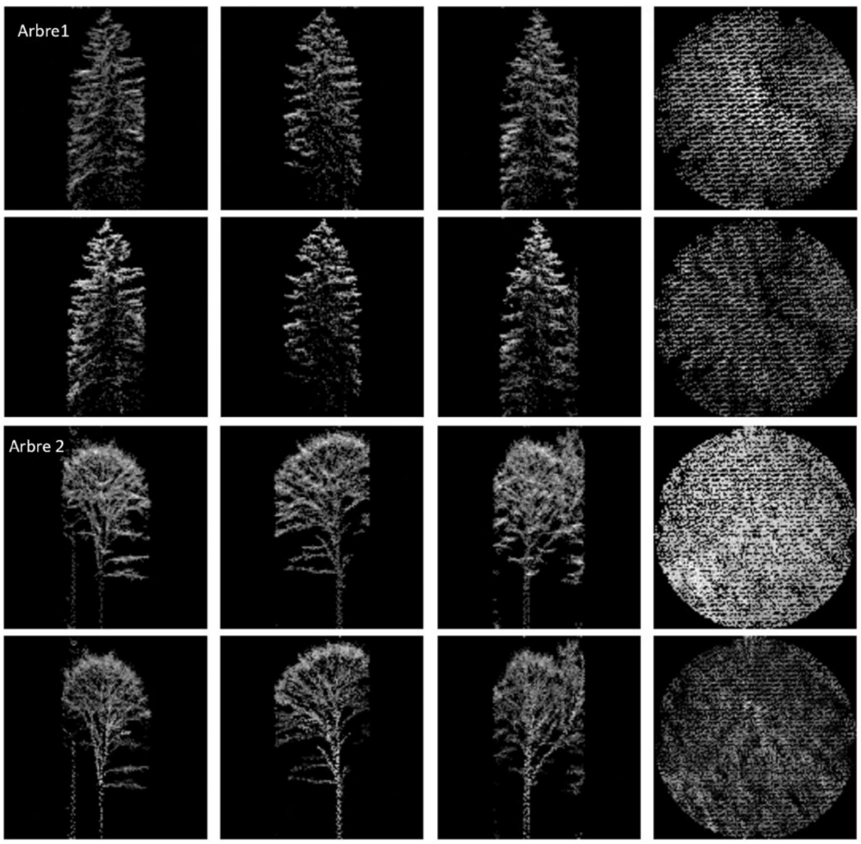

Figure 8: Profiles extracted from the point cloud for two trees. The top line in each pair represents the point density, and the bottom line represents the lidar return intensity.

Overall, conifers are much better differentiated than broadleaf species (**Table 2**). This is readily explained by their characteristic shape and by the fact that they keep their needles in winter, when the lidar data is acquired. Using the trained classification model, it is possible, thanks to the tree segmentation presented in the previous section, to determine the species of all trees in the canopy on the entire territory of Neuchâtel. The result is an automatic identification of tree species throughout the canton, down to the individual tree — information that did not previously exist. Such an automatic inventory supports precise, large-scale analysis of species distribution and makes it possible to monitor how it changes over time. The model is not perfect. Like any AI algorithm, it makes mistakes, sometimes systematically. We note that trees at the forest edge are often misidentified, and the same holds true for isolated or small trees. The training dataset is also biased: some species are underrepresented. Finally, the algorithm focuses only on 80% of trees, despite the diversity and complexity of Neuchâtel's forests. The 2D map shown in **Figure 9** is the first published canton-wide tree species map of Neuchâtel, with approximately 10 million trees identified. It can be used to analyze both the overall distribution of tree species and their detailed spatial patterns. **Figure 10** shows a forest sector where the point cloud has been colorized by tree species, while **Figure 11** presents a cross-section of the segmented and classified point cloud.

Some species, however, are harder to tell apart. Norway maple, for example, is often mistaken for other maples, for which the model has too little training data.

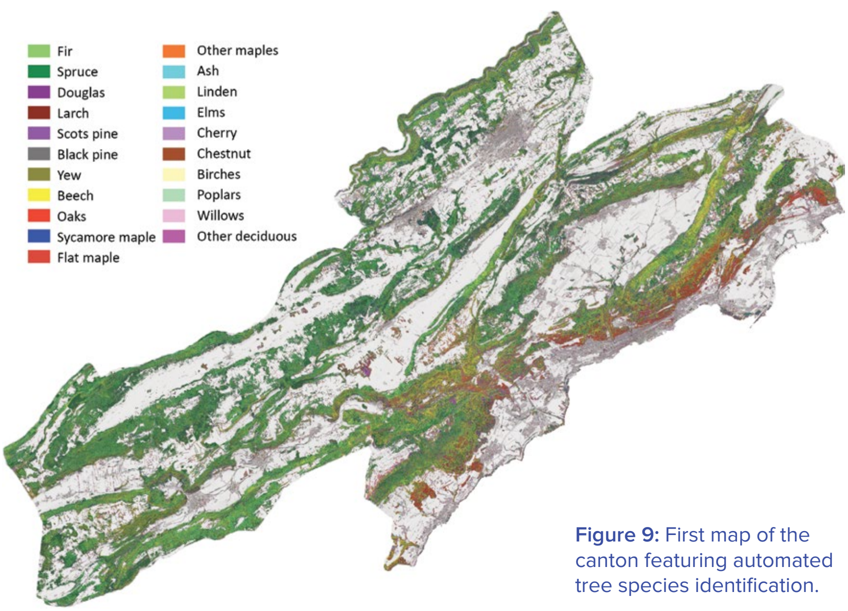

Figure 9: First map of the canton featuring automated tree species identification.

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Tree species	Accuracy	Tree species	Accuracy
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Douglas	96%	Beech	80%
Silver Fir	86%	Ash	88%
Spruce	90%	Poplars	67%
Scots pine	95%	Cherry tree	90%
Black pine	86%	Oaks	90%
Yew	95%	Willows	72%
Maples	84%	Linden	82%
Norway maple	62%	Elms	78%
Sycamore maple	84%	Other deciduous	52%
Birches	79%		

Table 2: Accuracy of tree species identification using the SITN model.

trees in the canopy and in forested areas. Trees located in the understory are much more difficult to distinguish. Urban areas contain a far wider range of species, often planted and pruned, which makes them harder to tell apart. SITN is actively working to develop models able to handle such trees, as climate adaptation challenges are also very significant in urban environments.

Conclusion and outlook

Since the advent of lidar data in the early 2000s, SITN's goal has been to turn the large and relatively complex datasets produced by this advanced measurement technology into operational products and maps directly usable by forestry professionals. The idea is to develop methods to automatically interpret the forest, from the cantonal scale for an overview down to the individual tree for detailed analysis. A very close and effective collaboration has been established with the Neuchâtel Forest Service to adapt data acquisition and products to forestry needs. The segmentation of individual trees and the detection of major tree species represents a significant step toward achieving this goal. As new generations of high-density lidar surveys become available, the long-term vision is to enable nationwide, tree-level forest inventories in Switzerland and to inspire similar initiatives internationally.

We continue to work on improving our algorithms to enhance the accuracy of our products and extract new metrics. These include, in particular, the estimation of diameters and volumes, paving the way for automated inventories that complement current field inventories, where tree species and dendrometric statistics can be computed for each forest management unit as illustrated in **Figure 12**. Work has also begun on analyzing understory vegetation, with promising early results. SITN welcomes collaborations on lidar-based forest mapping.

The challenges we face in preserving our forest ecosystems, which are under pressure from climate change, are immense. Lidar technology and geomatics tools will play a crucial role in understanding, monitoring, and preserving forest ecosystems under climate change.

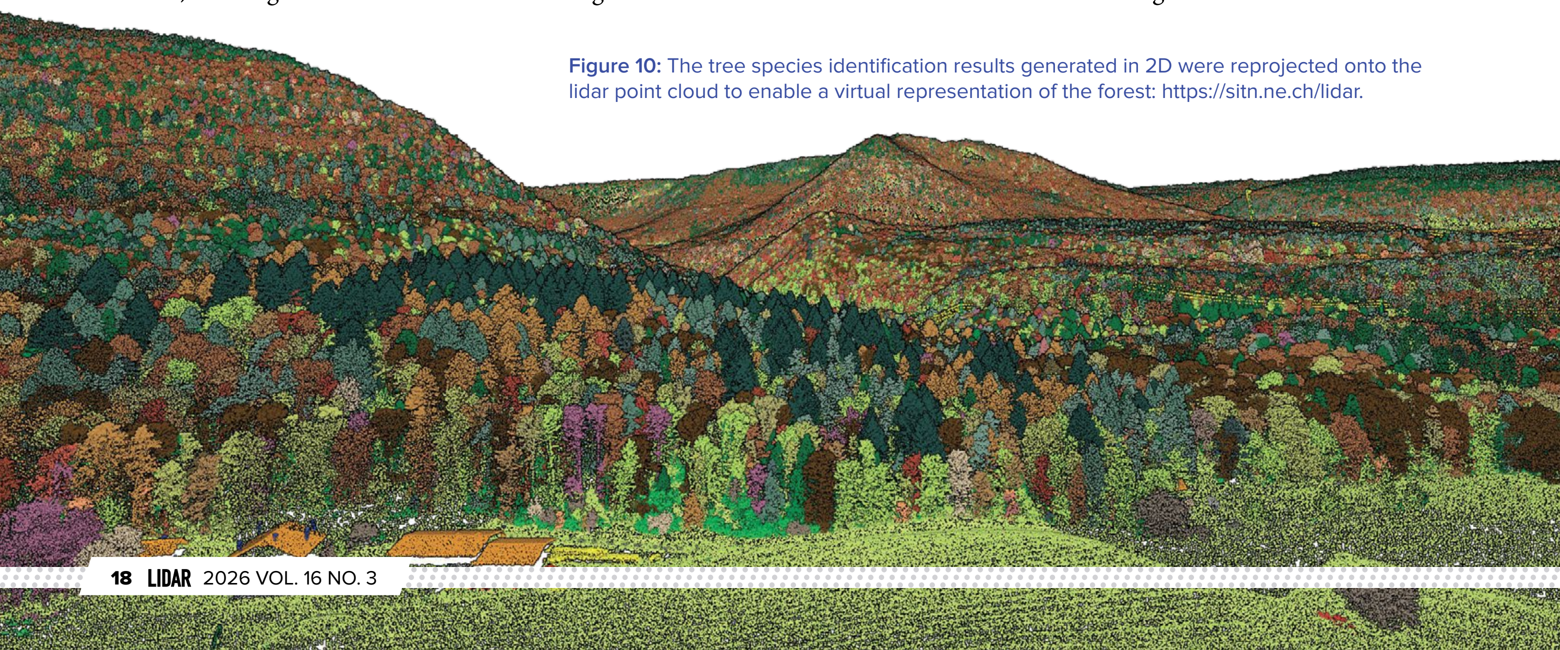

Figure 10: The tree species identification results generated in 2D were reprojected onto the lidar point cloud to enable a virtual representation of the forest: https://sitn.ne.ch/lidar.

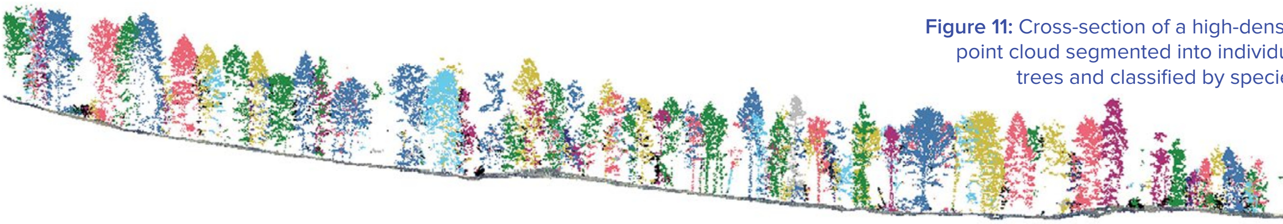

Figure 11: Cross-section of a high-density point cloud segmented into individual trees and classified by species.

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We thank the teams at Swiss Flight Services and Flotron for the exceptional quality of the data provided for the 2022 and 2025 lidar surveys, and forestry engineers Pascal Junod, Romain Blanc, and Frédéric Wyss for a demanding and exemplary collaboration.

Links and notes

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SITN and ASIT are organizing the Swiss lidar 2026 conference on November 10, 2026, at Le Cube in Morges. Save the date if you'd like to learn more about the data and the technology behind it.

The following links provide more information on topics mentioned in the article:

- Digital surface models (DSMs): https://sitn.ne.ch/s/geOuD
- Calculation of DSMs using ambient occlusion, C. Junod: https://github.com/sitn/DSM-Occlusion
- Digital elevation models (DEMs): https://sitn.ne.ch/s/34bcQ
- Relief visualization toolbox, Ž. Kokalj et al.: https://rvt-py.readthedocs.io/en/latest
- Spikefree DSM: A. Khosravipour, A. K. Skidmore, M. Isenburg: https://rapidlasso.de/generating-spike-free-digital-surface-modelsfrom-lidar
- Canopy height models (CHMs): https://sitn.ne.ch/s/qWJzi
- Surface vs. terrain comparison: https://sitn.ne.ch/s/lJpi
- Canopy differences: https://sitn.ne.ch/s/4ZrbW
- Differences in DSM for storm damage: https://sitn.ne.ch/s/t00So

Marc Riedo is head of the Neuchâtel GIS Center – SITN. **Dr. Matthew Parkan** and **Corentin Junod** are project managers at SITN.

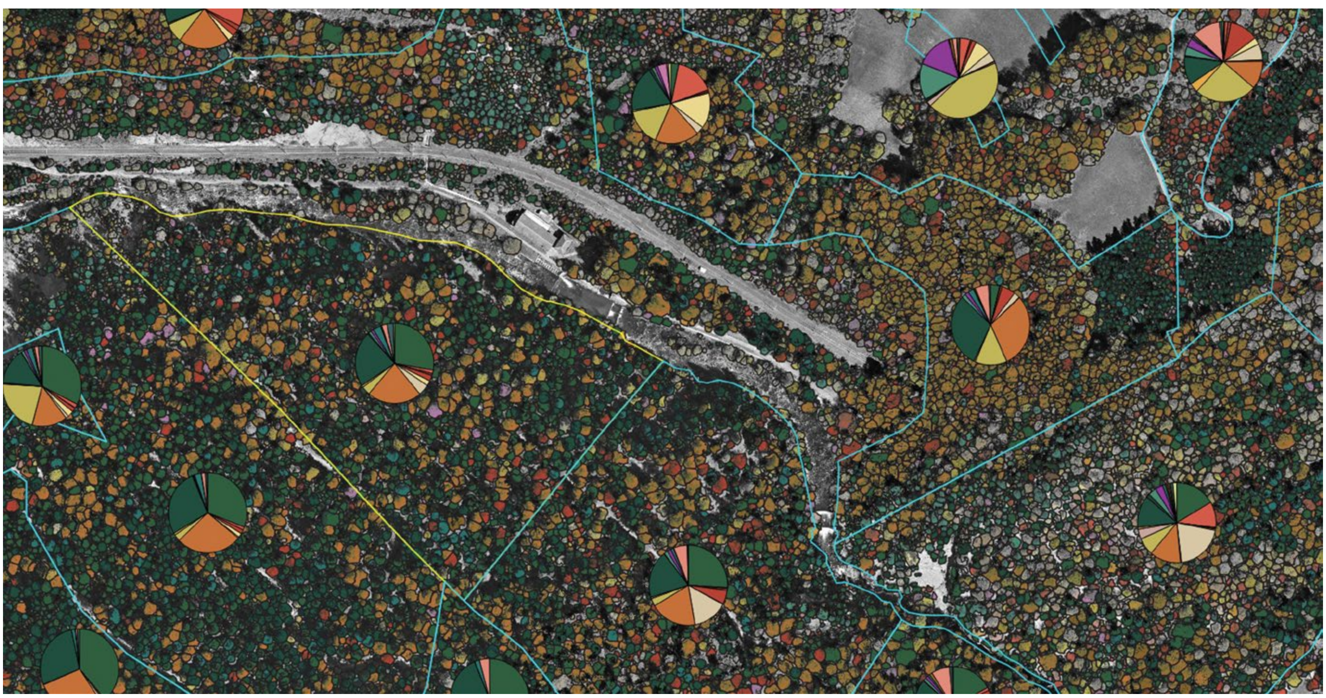


Figure 12: Tree attributes derived from lidar: distribution of tree species by management unit.

Beyond Accuracy

Volatus Aerospace drone stationed on a launch pad.

How sensor fusion is building a more resilient, reliable world: From Himalayan rail tunnels to airport drone corridors, the same technology is redefining what reliable positioning means

For most of its history, the positioning and mapping industry has measured progress in centimeters. How accurately can you place a point? How tightly can you constrain the error? Accuracy was the ultimate arbiter of a system's worth and in surveying, engineering and infrastructure, the cost of being wrong is very real.

But today, accuracy alone is no longer enough. The environments in which positioning systems operate are more complex, more constrained, and, in some regions, openly challenging to GNSS. Customers are no longer satisfied with, "How accurate is it?" They want to know, "Will it keep working when conditions change, and can I trust it in real-time?"

That shift is putting resilience, reliability and confidence at the center of system design. It's reshaping how the industry thinks about sensor fusion, correction services and trajectory management.

In the following, you'll see that it's the common thread running through three different deployments: a mobile mapping system built for electric vehicles in urban environments, a rail survey platform operating through Himalayan tunnels, and an autonomous drone navigating active airport airspace. Three industries, three continents, three radically different operational challenges — each underpinned by the same goal: positioning that doesn't quit when the environment pushes back.

BY KEVIN **ANDREWS**

The intelligence advantage

Mobile mapping has always been a power-hungry discipline. Traditional survey rigs laden with lidar scanners, cameras, GNSS receivers and inertial

A vehicle-mounted mobile mapping system equipped with a 360-degree camera setup.

measurement units demand specialized vehicle installations and significant power draw. For electric vehicles, where every watt reduces operational range, that has been a barrier to adoption.

Horus[1] set out to change that. Its goal was a professional-grade mapping system capable of centimeter-level accuracy running entirely off a standard 12-volt vehicle port. The result integrates GNSS and inertial positioning with lidar, thermal and optical sensors into a single-cable, lightweight platform representing a genuine engineering achievement in spatial and temporal precision at minimal power. By building on Trimble® Applanix's sensor-fusion engine and trajectory-focused processing, Horus gains not just accuracy but the kind of consistency and robustness on which mobile mapping workflows depend.

A key part of that robustness is the use of Trimble RTX® correction services, providing a consistent, high-accuracy reference frame across large operating areas without the need to renegotiate real-time kinematic (RTK) networks as vehicles move between regions. That gives operators confidence that the positioning solution will behave the same way from city to city and country to country.

What makes this deployment particularly forward-looking is edge AI. Rather than storing raw data for office post-processing, the system pairs its positioning hardware with onboard GPUs that run AI models in real time as the vehicle drives, detecting and classifying infrastructure assets, road signs and environmental conditions on the fly. The result is a 40 percent reduction in field time and, more significantly, a more resilient, automated workflow that reflects where the industry is heading: positioning systems that don't just capture the world, but understand it and maintain operational continuity as conditions change.

Continuous corridors

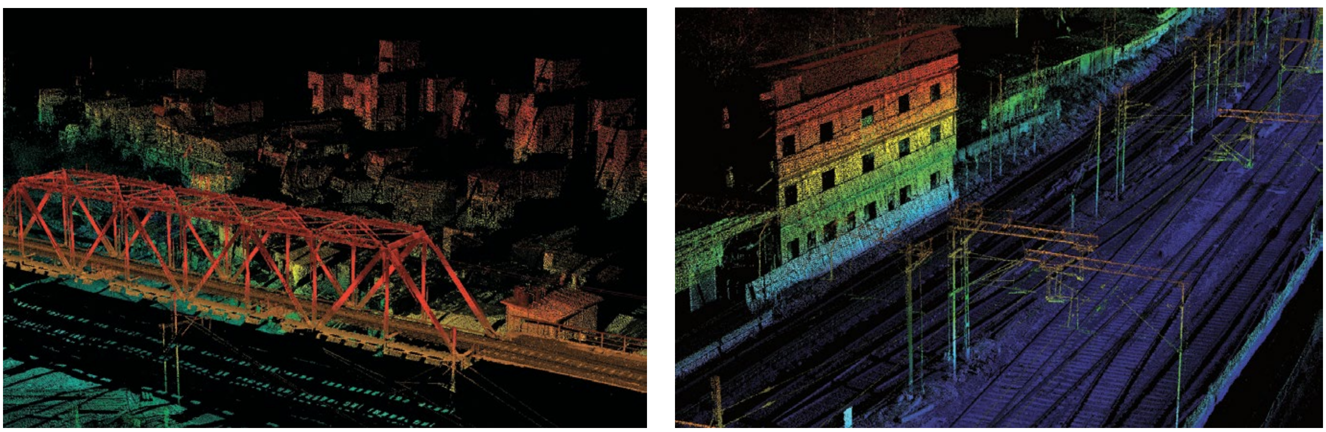
While urban mobile mapping pushes the limits of efficiency and power, rail infrastructure demands positioning that can survive total blackout conditions.

Rail networks present some of the most challenging positioning environments on earth. Trains move at speed through tunnels, dense forests,

1 https://applanix.trimble.com/resources/applanix/en-US/case-study/how-horus-drives-mobile-mapping-to-the-edge

deep mountain valleys, and urban canyons — all of which block or degrade GNSS signals. A rail survey system that depends on satellite positioning alone will produce accurate data in open country and useless data everywhere else. For a network that may run for hundreds of kilometers through varied terrain, that is not acceptable.

An urban mapping vehicle equipped with roof-mounted sensors and cameras, parked on a city street while collecting data.



Left: 3D lidar point-cloud scan highlighting a steel truss railway bridge; right: 3D lidar point-cloud scan of a railway corridor and a multi-story building, color-coded by elevation.

Roter Precision[2], a rail survey company, operates in exactly these conditions, including some of the most demanding terrain on the planet. Their system achieves continuous, accurate positioning through deep sensor fusion built around a tightly managed trajectory. GNSS provides absolute positioning when the sky is clear; an inertial measurement unit, which measures acceleration and rotation, carries the solution through GNSS-denied segments using dead reckoning from the last known fix; and a distance measurement instrument tracking wheel rotation provides precise speed data that keeps the trajectory stable over extended signal outages. By treating the trajectory as the common thread that ties all sensors together, Roter maintains a solution that is not only accurate, but predictable and engineerable, and thus the basis for a resilient workflow rather than a fragile one.

The output is a continuous, high-fidelity 3D digital twin of the rail corridor that does not have gaps where the tunnels are. This supports clearance analysis, track alignment verification, and the kind of ongoing infrastructure monitoring — comparing this month's scan against last month's — that enables predictive maintenance before a structural problem becomes a safety incident.

This is resilience in its most literal sense: a system engineered to ensure

2 https://www.linkedin.com/posts/centimeter-level-3d-railway-models-ugc-Post-7389687056089636864-_HWP/

uncompromised data integrity, through the very conditions that would break a less integrated approach.

Resilience through safety

True resilience is tested not just by difficult geography, but by environments where the consequences of failure are measured in terms of human safety.

Drone logistics are maturing rapidly, and the frontier of that evolution is autonomous operations in and around major airports. Automated delivery routes could dramatically reduce ground transport in dense urban areas, but the regulatory and technical bar is extraordinarily high. A drone crossing an active runway glide path is operating in some of the most tightly controlled airspace in the world, close to commercial aircraft carrying hundreds of passengers.

The positioning challenge is compounded by the airport itself. Terminal buildings, radar installations, and the density of radio frequency (RF) traffic create a challenging signal environment laden with multipath reflections, temporary signal dropout, and interference that would cause a purely GNSS-dependent system to behave unpredictably. Vision-based positioning systems, sometimes proposed as alternatives, are unreliable in poor visibility, low light, and adverse weather. Neither system is sufficient on its own.

Volatus Aerospace[3], a Canadian aerospace and defense company, needed to fly autonomous delivery routes across an active international airport, crossing live runway glide paths, without relying on ground-based positioning infrastructure. By integrating GNSS and inertial sensors into a tightly coupled system and using Trimble RTX as a consistent global reference, the team achieved centimeter-level accuracy even when satellite signals blink out for seconds at a time. When GNSS is unavailable because it is blocked by a terminal building, reflected off a jetway, or overwhelmed by adjacent RF traffic, for example, the inertial sensors seamlessly maintain the solution, delivering all-weather, all-condition positioning without any additional airport infrastructure.

This infrastructure independence matters enormously for scalability. A system that carries its resilience with it through the integration of its sensors and the consistency of its correction service can operate under a single workflow across any airport, in any country, in any weather. The autonomous flight systems aboard these drones consume that positioning data to make hundreds of real-time decisions per second: adjusting rotor speeds, compensating for wind, and executing precise landings on small pads near active terminals. The accuracy of that data is not an abstract quality metric. It is the basis for operator and regulator confidence, and the direct enabler of safe autonomous operation in controlled airspace.

Raising the reliability bar

Three deployments, three industries, three continents with a single architectural principle at the heart of each: a precise, continuous trajectory that ties all sensor data together. This allows a lidar point captured at a specific millisecond to be placed accurately in three-dimensional space. It enables data from multiple sensors, each with its own clock, coordinate frame, and error characteristics, to be fused into a coherent whole.

What makes trajectory-based fusion so powerful is predictability. Trajectory errors have characteristic signatures, they drift in recognizable ways, correlate with identifiable conditions, and can be modeled and corrected for. That predictability is why a well-designed fusion system can bridge a tunnel where GNSS is lost, maintain accuracy through the multipath environment of an airport, or synchronize a lidar scanner to microsecond precision. Errors become predictable adjustments rather than systemic failures.

GNSS/IMU/LIDAR INTEGRATION IS DEMANDING

The integration of the positioning backbone with lidar scanning requires precision at two levels. Spatial integration demands that the exact physical offset between the GNSS antenna and the lidar scanner be calibrated to the millimeter. Any error in that relationship translates directly into positional error in the point cloud. Temporal integration requires the clocks of both systems be synchronized to a fraction of a millisecond; at survey speeds, even tiny timing errors produce visible distortion in 3D data. On top of that, a consistent correction source (such as Trimble RTX) allows the same processing approach to be applied as trains move between regions, supporting a single, repeatable workflow instead of a patchwork of local solutions.

3 https://volatusaerospace.com/

Close-up of Volatus Aerospace cargo drone.

Supporting all three deployments is access to satellite-delivered correction services that work consistently anywhere in the world, thereby eliminating the infrastructure dependency of traditional ground-based RTK and providing one workflow, one quality standard, everywhere from Tokyo to Toronto, from the Himalayas to Heathrow.

Sensor fusion is not new. What has changed is its maturity and accessibility. Where once it demanded deep specialist expertise and painstaking calibration, that complexity is increasingly absorbed into the tools themselves. Today, advanced fusion is made practical for more operators in more applications, thanks to automated quality checks, trajectory anomaly detection, and streamlined correction workflows.

This progress matters more now because the environment has become more challenging to GNSS. Signals that operators once took for granted are subject to disruption from congested RF environments, natural interference, and, in growing parts of the world, deliberate jamming and spoofing driven by geopolitical conflict. The answer is not better antennae alone, but systems that do not depend on any single input remaining available - where losing a satellite signal is a manageable event, not a failure.

These three deployments point to where the industry is heading: positioning systems that are not just accurate, but genuinely resilient systems that carry their reliability with them, wherever they go.

As Director, Land and Air for Trimble, **Kevin Andrews** leads a team responsible for delivering advanced solutions and technologies to markets that require highly accurate positioning and orientation for the purposes of reality capture on moving, ground-based platforms. Previously, Kevin was the strategic marketing manager for businesses at Trimble that serve autonomous vehicle applications and, prior to that, product manager for Trimble's Applanix land and indoor products. Kevin received his MBA from Schulich School of Business and BSc in Geomatics Engineering from the University of Calgary. He lives in the Toronto area with his wife, children and two cats.

Kings Bay/Crystal River, Florida – 10 Years Later

Comparison of bathymetric lidar surveys through time confirms reliability

Kings Bay in Crystal River, Florida (**Figure 1**) was designated as an Outstanding Florida Water and an Outstanding Florida Spring by the state. This 600-acre bay is the headwaters for Crystal River and is a first magnitude spring system, comprising over 70 springs. The spring water is 72°F (22°C) year-round, attracting wildlife and outdoor enthusiasts alike, which adds an economic driver to the bay's environmental importance. Designated as a national wildlife refuge in 1983, this system harbors over 1,000 West Indian manatees (*Trichechus manatus*) during the winter and draws

BY AL **KARLIN,** NICOLE **HEWITT,** MADISON **TROWBRIDGE**

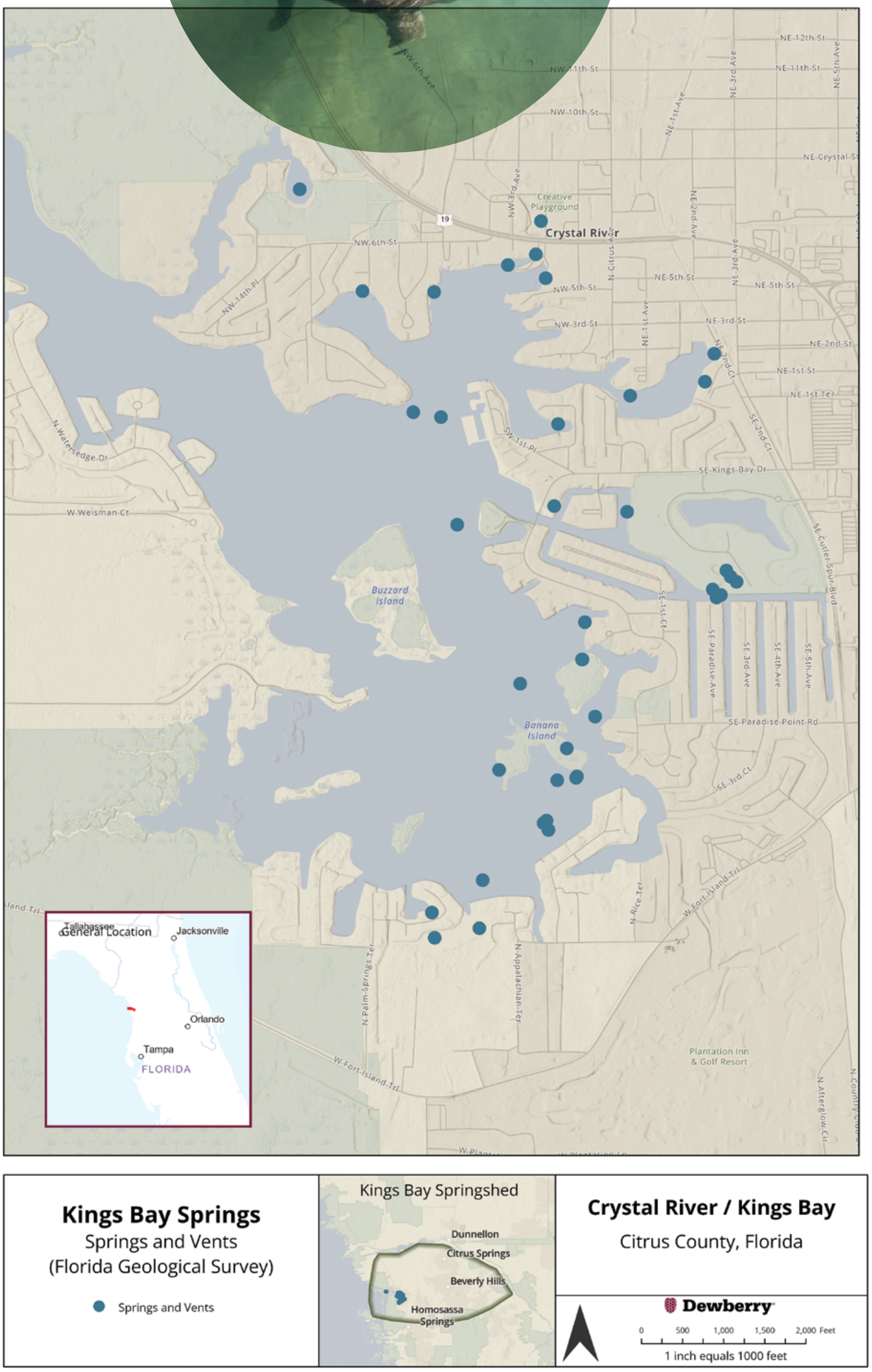


Figure 1: Kings Bay, Citrus County, Florida location map, showing the distribution of springs and vents.

nearly 400,000 visitors annually to swim with the manatees. Numerous government agencies, non-profit organizations, and businesses are listed as stakeholders in the Crystal River/ Kings Bay Basin Management Action Plan by the Florida Department of Environmental Protection (FDEP), all having a vested interest in Kings Bay, along with local residents. Considering the substantial attention on Kings Bay, periodic acquisitions of its bathymetry are well warranted.

Bathymetric lidar projects (**Table 1**) have been conducted in Kings Bay over the past decade by the Joint Airborne Lidar Bathymetric Technical Center of Expertise (JALBTCX; now the Interagency Airborne Technologies for Lidar Analysis and Surveying (I-ATLAS)), the National Oceanic and Atmospheric Administration (NOAA), and the Southwest Florida Water Management District (SWFWMD). Each of these surveys acquired topo-bathymetric lidar and produced derived digital elevation model (DEM) raster products. As with any comparison of DEM products over time, product variations and temporal differences must be taken into consideration when evaluating change detection results.

The first topobathymetric lidar acquisition occurred in spring 2015, when SWFWMD conducted a cooperative pilot project with JALBTCX and Dewberry. JALBTCX deployed a Teledyne Optech Coastal Zone Mapping and Imaging Lidar (CZMIL) sensor to collect topobathymetric lidar data for a portion of the Kings Bay springs system (**Figure 2**). This project was conducted to determine the feasibility of using topobathymetric lidar to map the inland spring system. During

Project year	2015	2020	2025
Agency	JALBTCX	NOAA	SWFWMD
Company	Dewberry	Quantum Spatial (now NV5)	Dewberry
Sensor(s)	Teledyne Optech CZMIL	Leica Chiroptera 4X	Teledyne Optech CZMIL-2 SuperNova
DEM resolution	1 m	1 m	2.5 feet
Horizontal datum	NAD83 (NSRS2007)	NAD83 (2011)	NAD83 (2011)
Vertical datum	NAVD88 (GEOID 12B)	NAVD88 (GEOID 18)	NAVD88 (GEOID 18)

Table 1: Topobathymetric lidar surveys of Kings Bay (2015, 2020 and 2025; see **Figure 3** for survey distribution).

that same time period, SWFWMD engaged a local hydrographic survey firm to employ "traditional" survey instruments, a single-beam fathometer (Teledyne Marine Odom Echotrac MK III, operating at 200 kHz) and a low-frequency sub-bottom profiler (Ross 8510, operating at 3.5 kHz), to survey the Kings Bay bathymetry. Thus, this acquisition project provided an opportunity to compare the CZMIL lidar-derived measurements of top and bottom of unconsolidated materials (i.e., derived volume) with comparable volumes derived from conventional hydrographic surveys.

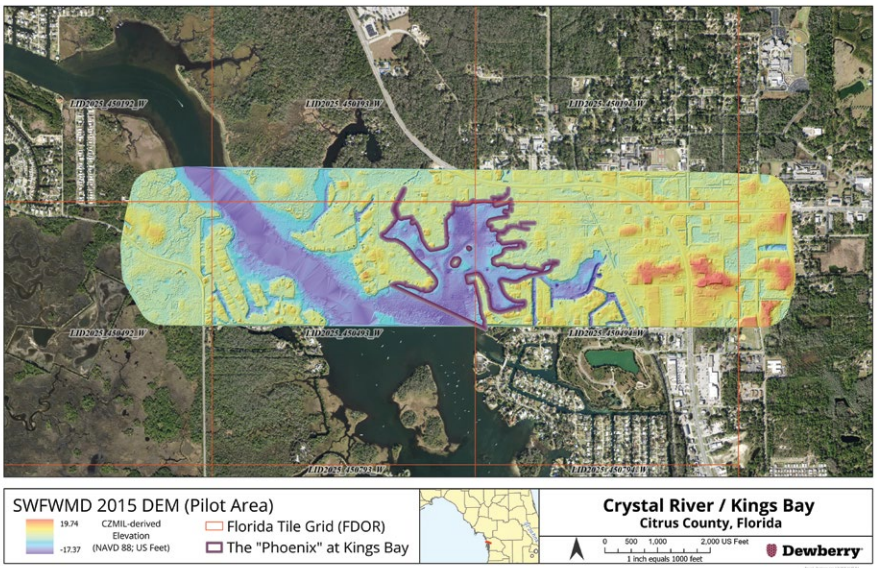


Figure 2: DEM constructed from 2015 topobathymetric lidar survey highlighting the "Phoenix" area of Kings Bay.

Pilot project area and the 2015 results

The area selected for the Kings Bay pilot project is commonly called the "Phoenix" because the general shape of the area resembles a flying phoenix (**Figure 2**). This area, of approximately one square mile, contains numerous springs (**Figure 1**), over 250 residences, tourist businesses, restaurants, and a commercial fishery. A commercial shipping channel leads from the fishery out through Kings Bay proper and into the Crystal River for approximately seven miles, where the Crystal River empties into the Gulf (**Figure 3**).

The results were reported in detail in *LIDAR Magazine* (Karlin et al., 2017).

The close agreement between the CZMIL lidar ranges and the conventional sonar survey provided SWFWMD with a high level of confidence in the accuracy of the lidar-derived surfaces used for volumetric calculations.

SWFWMD instructed its consultants to proceed to use the CZMIL lidar data, *in lieu* of the sonar survey data, for all unconsolidated sediment thickness analyses, design drawings and conceptual options of probable cost for sediment removal.

SWFWMD found that surface interpolations using the sonar data may introduce greater error than the lidar data, likely resulting from the karst geology and large survey transect interval (100 feet). Indeed, the sonar survey completely missed a large, first-order spring vent simply as a result of the transect interval.

Based, in part, on these results in the Kings Bay system, and reinforced

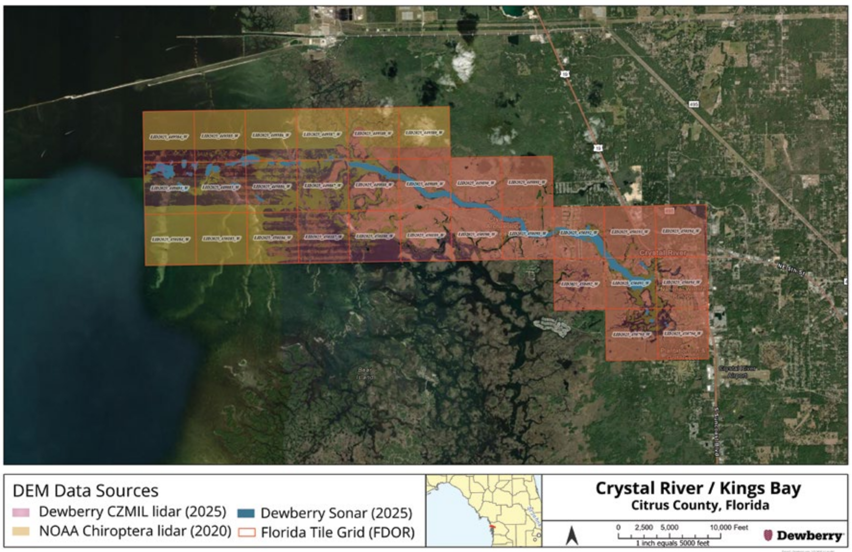


Figure 3: Crystal River/Kings Bay, Citrus County, Florida, showing the distribution of the 2020 NOAA (lidar) and 2025 SWFWMD (lidar and sonar) surveys.

by similar satisfactory results from the Rainbow River (Karlin et al., 2020), and Gum Slough (Karlin et al., 2023), both inland tributaries of the Withlacoochee River, Dewberry proposed a hybrid topobathymetric lidar/multibeam sonar approach to remapping the full extent of Kings Bay, including the entire length of the Crystal River, for SWFWMD's Minimum Flows and Levels (MFL) modeling. The details of this study and change detection analysis between 2015 and 2025 are reported below.

Topobathymetric lidar data sets for change detection — some considerations

With the 10-year separation between lidar missions, variations in sensors, resolution, and datum inevitably influence the lidar data quality and thus the resultant products. **Table 1** lists sensors, DEM resolution, and geodetic datums for the different acquisition times. Quadros (2013) provides a detailed sensor comparison.

NOAA's National Geodetic Survey (NGS) provides the framework for all positioning activities in the nation. For the horizontal datum, the increasing accuracy and availability of GNSS led to the two adjustments of the NAD83 datum (2007 and 2011) as adopted by SWFWMD for the 2015 and 2025 missions, respectively. For the vertical datum, GEOID18 (adopted by SWFWMD in 2020) is a significant improvement over GEOID12B (adopted by SWFWMD in 2012), including improvements to the underlying gravimetric geoid model, with consequent increases in the accuracy and distribution of data used to constrain the bathymetric ground model to established benchmarks. As expected, significant new data analysis and advances in modeling techniques also were developed.

Custom lidar bathymetric ground algorithms may also produce variations between projects in coverage of points classified as bathymetric bottom (ASPRS Class 40), which, in turn, may affect the DEM comparisons. Areas with insufficient point density may be enforced in the DEM as data voids, as was common in the 2020 NOAA project, or the DEM may be allowed to interpolate across low density areas, as in the 2015 JALBTCX project. The locations of the voids or areas of interpolation are sometimes but not

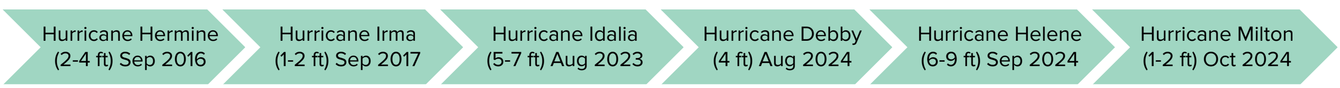


Figure 4: Timeline of tropical storms that influenced sediment deposition in Kings Bay.

always the same between projects. Elevation differences occurring in these void areas are not valid results. It is best practice to exclude these areas from DEM comparisons.

Temporal differences between the data sets

In addition to product variations, temporal differences must be taken into consideration when evaluating DEM change detection results. The temporal difference of natural sediment accumulation over time is expected in Kings Bay. Additionally, several severe weather events over the intervening decade (**Figure 4**) potentially affected the benthic bottom elevations. The storm surge heights in the Crystal River area

Parameter	Value
Altitude	400 m above ground
Nominal flight speed	100 knots
Scan frequency	27 Hz
Multiple pulses in the air	Yes
Beam divergence	5 milliradians
Swath width	290 m
Swath overlap	30%
Total sensor scan angle	40 degrees
Nominal pulse spacing (single swath)	0.34 m
Nominal pulse density (single swath)	8.5 points/m^2
Maximum number of returns per pulse	15
NOTE: Scanner pulse rate (kHz), pulse duration (nanoseconds), and pulse width (m) are proprietary Teledyne Optech values	

Table 2: CZMIL-2 acquisition parameters for the Crystal River/Kings Bay survey.

Parameter	Value
Number of flightlines	55 total: 33 east-west, 19 northwest–southeast; 3 cross lines
Acquisition dates	23 April 2025 – 5 May 2025
Horizontal datum	North American Datum of 1983 with the 2011 Adjustment (NAD83/2011)
Vertical datum/geoid model	North American Vertical Datum of 1988/ GEOID18
Coordinate reference system	Florida State Plane Coordinate System, West Zone (0902)
Horizontal units	US Survey feet
Vertical units	US Survey feet
Kinematic solution processing software	Applanix POSPac
Point cloud generation software	CARIS BaseEditor
Calibration software	BayesMap StripAlign

Table 3: Topobathymetric lidar delivery parameters for the Crystal River/Kings Bay survey.

are displayed in the timeline, according to National Hurricane Center Tropical Cyclone Reports. Although Kings Bay is six miles inland from the Gulf of America and generally sheltered from the worst wave action during hurricanes that typically causes erosion, the bay is nonetheless subject to rapid sediment deposit from storm surge.

Finally, construction/dredging projects in the area during the interim between lidar collections were reviewed and only one United States Army Corps of Engineers (USACE) permit application SAJ-2016-00169 (SP-EWG) was found to be a potential influence on bathymetry. The purpose of the project by Save Crystal River, Inc. in 2022 was to suction-dredge a total of 29,400 cubic yards of muck containing *Lyngbya spp*. algae and other dead and decaying detrital material from the eastern and northern extent of Kings Bay, to expose a mineral substrate that is suitable for planting native aquatic vegetation. As this dredging occurred three years prior to the topobathymetric survey, was limited to a small area, and there were several natural events during the intervening time, most likely this project had little effect on the "Phoenix" sediments.

2025 CZMIL-2 topobathymetric lidar data set

The primary data set used to construct the final "hybrid" digital elevation models (DEMs) was the CZMIL-2 topobathymetric lidar data. Data collection was planned for 52 parallel flight lines, 33 east-west lines to map the extents, and an additional 19 northwest–southeast lines tailored to the bay, with 3 cross flightlines over the area of approximately 27 square miles. Because this area serves

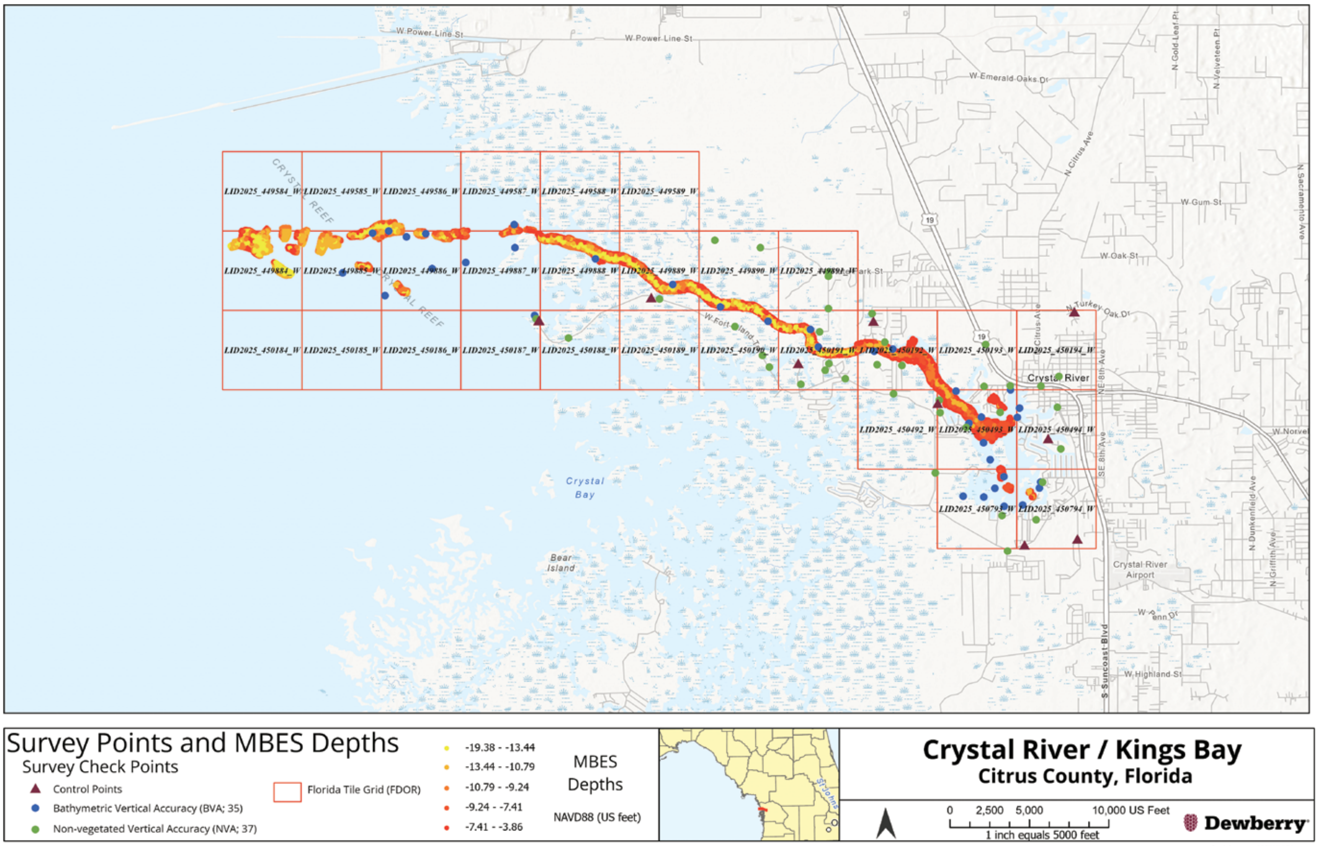


Figure 5: Distribution of multibeam echosound (MBES), single-beam echosound (SBES) and acoustic checkpoint surveys.

as a warm-water refuge for more than 1,000 West Indian manatees during the winter months, aerial acquisition was delayed until 23 April 2025, after the manatees left the bay. Aerial data acquisition was completed on 5 May 2025. All lidar data were collected with the parameters in **Table 2** and delivered with the parameters in **Table 3**.

Multi-beam sonar data set and ground truth survey

Sonar data: To fill-in CZMIL-2 voids, as a secondary data source, and to ground truth the CZMIL-2 data, Dewberry contracted with SurvTech Solutions, Inc. (Tampa, Florida) to acquire conventional multibeam sonar (MBES) data along the reach of the Crystal River, through selected areas within Kings Bay (**Figure 5**), acquire six (6) single-beam sonar cross-sections at pre-selected locations along the Crystal River, and perform lidar control and ground truth surveys (**Figure 5**). Vessel-based survey was performed with either a 22-foot cabin boat or a 10-foot pontoon boat as constrained by the river. Sonar surveys were conducted with a CEESCOPE Echosounder (single-beam) and either a Norbit iWMBS + Applanix AP20 or PingDSP multibeam sonar system. Single-beam sonar was collected on 13 June 2025; multibeam, on 19–25 June 2025.

Survey Control and Ground Truth Data: All ground positions were measured with Trimble R10 (base), Trimble R8 (rover) and Trimble TSC5 (controller). The primary control for the survey was NGS control point CR52, which was verified and referenced to three other NGS control points using the Florida Department of Transportation's Florida Permanent Reference Network. Ten ground control points (GCPs) were collected relative to CR52. To conform to ASPRS Positional Accuracy Standards for Digital Geospatial Data (2023)[1],37 Non-Vegetated Accuracy (NVA) check points and 35 Bathymetric Vertical Accuracy

1 https://www.scribd.com/document/699356841/2023-ASPRS-Positional-Accuracy-Standards-Edition2-Version1-0

(BVA) checkpoints were surveyed (**Figure 5**). NVA check points were surveyed on 11–24 September 2025; BVA checkpoints, on 3–4 June 2025. All check points were reported to the same horizontal and vertical datums, and coordinate reference system as the lidar, as indicated in **Table 3**.

2019-2020 NOAA NGS topobathymetric lidar: Hurricane Michael (NW Florida) data set

An additional supplemental data source was the NOAA Michael topobathymetric lidar project area acquired between November 2019 and July 2020 by Quantum Spatial using a Leica Chiroptera 4X topobathymetric lidar system (**Figure 3**). Details for this dataset can be found in the metadata on the NOAA Digital Coast (https://www.fisheries.noaa.gov/inport/item/69189).

2015–2025 comparison in the "Phoenix"

The pilot (2015) project dataset was focused on the volumetric measurements in the "Phoenix" portion of Kings Bay, so the bathymetric surface comparison to the 2025 CZMIL-2 dataset was limited to that area. The bathymetric DEMs for the "Phoenix" contained 536,354 2.5' x 2.5' cells. The horizontal and vertical datums were adjusted using VDatum (https://vdatum.noaa.gov/) to match the 2025 data set, and a difference DEM was constructed by subtracting the elevation values of the 2015 surface from the 2025 surface (**Figure 6**).

The difference DEM (**Figure 6**) revealed elevation differences ranging from -11.5 to +11.1 feet, with an average difference indicating that the 2025 DEM was 0.50' lower than the 2015 DEM. The standard deviation around the mean (±1.12 feet) and the skewness (1.56) suggests a normal distribution of the error (**Table 4; Figure 7**).

The largest differences were primarily localized to two areas (**Figure 6**). The -11 foot difference corresponds to a deep pit that was either missed or not present in the 2015 survey. Examination

Statistic	Dataset (Entire)	Dataset (Selected)
Number of cells	536,354	500,463
Mean	-0.50	-0.49
Standard deviation	1.12	0.53
Minimum difference	-11.51 (feet)	-2.00 (feet)
Maximum difference	11.17 (feet)	1.99 (feet)
Skewness	1.56	0.75
Kurtosis	22.31	5.71

Table 4: Statistical summary for the difference DEM. The "Dataset (Entire)" column reports statistics for all cells within the "Phoenix" area, while the "Dataset (Selected)" reports statistics for the same area with deep and shallow regions excluded.

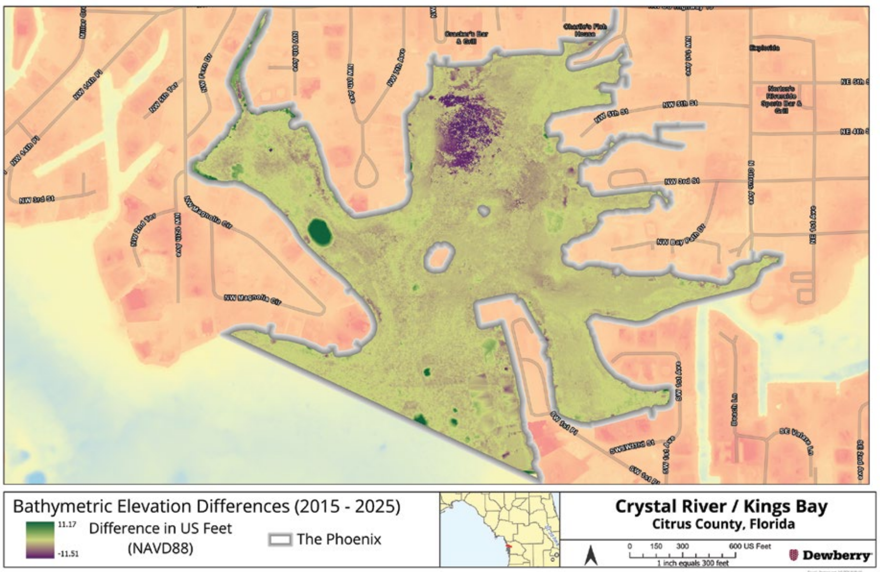


Figure 6: Difference DEM for the "Phoenix" area of Kings Bay constructed by subtracting the 2015 DEM from the 2025 DEM.

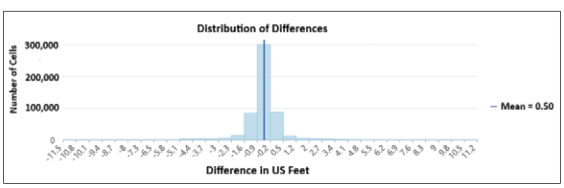


Figure 7: Distribution of differences in the difference DEM (entire dataset).

of the known springs from the Florida Geological Survey in Kings Bay does not indicate a spring at or near that location. SWFWMD Submerged Aquatic Vegetation (SAV) mapping station 101 is near this area and has been consistently between 5.0-6.5 feet deeper since 2021.

The converse, i.e., areas where the 2025 elevations are above those from 2015, occur mostly in a diffuse area in the "wing" of the "Phoenix" (**Figure 6**). This region is reasonably close to the commercial areas of the bay and probably has been experiencing sedimentation over the past 10 years. While kayaking through here recently, we noticed that the water was only a foot or two deep. SWFWMD does not have an SAV location in this specific area, but stations 1, 2, and 50 are nearby and their water depths can be less than three feet. Sediments have been moving around in this system for decades, and recent hurricanes (**Figure 4**) could have changed the bathymetry. For example, Hurricane Helene (late September 2024) deposited considerable sediments along the Springs Coast with reports of 1-2 inches of "muck" in people's houses. Additional storms in the area since 2015, for example, Idalia (August 2023), Hermine (August 2024), and Helene (September 2024), each brought storm surge into the bay while others, such as Ian (September 2022) and Milton (October 2024), caused reverse storm surge.

When the deep pit and shallow areas are removed from the analysis (**Table 5**, Dataset (Selected)) the mean difference among the remaining 500,463 cells decreases only to 0.49' (from 0.50'), but the standard deviation decreases significantly from ±1.12' to ±0.53', and the skewness decreases by almost 50% to 0.75. These values suggest that while the outliers in the pit and shallow areas contributed to the overall spread of the differences, they had little effect on the majority of the cell differences.

Conclusions

The differences in the mean, standard deviation, and skewness when the pit and shallow water cells are removed suggests (1) a normal distribution of the differences, (2) that the pit and shallow areas are real, and (3) that the CZMIL and CZMIL-2 topobathymetric lidar elevations are consistent within their margin of error (0.6') over the 10-year period.

In general, we find the two CZMIL topobathymetric lidar datasets to be consistent over the intervening decade. Considering changes in Kings Bay caused by different phenomena, the areas of major differences are minimal. This suggests that (1) CZMIL topobathymetric lidar, and probably topobathymetric lidar in general, as evidenced by the NOAA 2020 survey, produces consistent and reliable bathymetry for inland waterways, and (2) topobathymetric surveys separated temporally by a decade can help to understand general changes in bathymetry.

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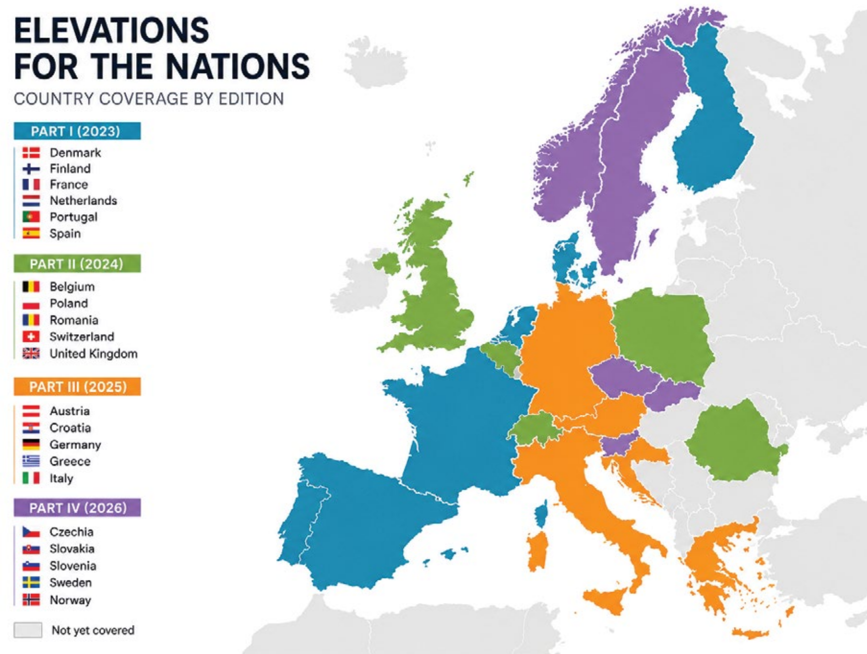
Elevations for the Nations

Understanding Europe's varied approach to lidar mapping

PART IV



European countries covered in the author's *Elevations for the Nations* series.

Mapping activities for the United States are centrally coordinated for a total area of about 3.8 million square miles. The U.S. Geological Survey's 3D Elevation Program (3DEP) now provides lidar-based elevation data for more than 99 percent of the nation. Across the Atlantic, the picture remains different. Europe's 3.9 million square miles are divided among some 50 sovereign nations, each with its own mapping mandate, budget reality, and political history.

This is the fourth instalment of *Elevations for the Nations*, produced in collaboration with the European Association of Aerial Surveying Industries (EAASI)[1]. Previous editions covered 16 countries: Denmark, Finland, France, the Netherlands, Portugal, and Spain (2023)[2]; Belgium, Poland, Romania, Switzerland, and the United Kingdom (2024)[3]; and Austria, Croatia, Germany, Greece, and Italy (2025)[4]. This edition adds five more: Czechia, Norway, Slovakia, Slovenia, and Sweden.

Each country profile is based on a five-question questionnaire sent to the national mapping and cadastral authority (NMCA). The questions asked about the current status of national lidar coverage; the value-added products derived from the data and how they are used by public authorities and the private sector; the point density selected and the reasoning behind it; innovative or AI-based applications currently in use; and perspectives on the prospects and challenges of a pan-European elevation dataset.

BY ADA PERELLO

1 eaasi.eu

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The answers varied considerably. Some agencies run large in-house processing operations with active R&D programs. Others outsource acquisition and classification entirely and focus on procurement design and product delivery. Both approaches are valid, and the contrast itself reveals how lidar capacity is being built across Europe.

A patchwork with common threads

Europe's lidar programs remain national at the operational level. Of the roughly 50 countries on the continent, 27 are EU member states; Norway, featured in this edition, is not.

Within the EU, two frameworks shape how elevation data is managed without dictating how surveys are flown. The INSPIRE Directive (Infrastructure for Spatial Information in Europe) sets technical specifications for the Elevation data theme, including data models, metadata obligations, and download services, but does not address point density, flight parameters, or update cycles. This is less a deliberate delegation than a reflection of the directive's timing: when INSPIRE was being defined, airborne lidar was not yet a standard national mapping tool, and the level of detail it now enables was not part of the regulatory conversation. The ongoing revision of INSPIRE may be an opportunity to address this gap.

The EU's Open Data Directive (2019/1024) and its implementing rules classify core reference geodata, including elevation, as "highvalue datasets" that must be made openly available in harmonized, reusable formats, typically via APIs and bulk download.

High-resolution oblique aerial image of the Prague Castle complex, Czech Republic.
Credit: PRIMIS.

Two pan-European bodies quietly do much of the alignment work. EuroSDR, the European Spatial Data Research network, has developed widely used practices for documenting point-cloud datasets through workshops and benchmark projects. EuroGeographics, the membership of which includes most European NMCAs, has delivered pan-European reference products in cartography and orthoimagery. Its EuroDEM product, built from member contributions, demonstrates that pan-European elevation data can be assembled from national sources — though its resolution and accuracy are far removed from what national lidar programs now deliver. Several agencies in this series have mentioned EuroSDR as a potential coordination umbrella for a future lidar initiative.

The practical consequences of this fragmentation are already becoming visible in scientific applications. Attempting to build a European Canopy Height Model from existing national ALS datasets, Moudrý et al. (2026)[5] found that a decade-old scan from the Giant Mountains National Park in Czechia outperformed all four leading satellite-derived canopy height models tested, with satellite errors ranging from 6.4 to 11.7 meters. The problem is not data quality — it is fragmentation. National datasets were not designed with vegetation structure in mind, and acquisition windows, point densities, and classification schemes diverge enough to make integration genuinely difficult.

5 Moudrý, V. *et al*. 2026. Spaceborne canopy height products should be complemented with airborne laser scanning data: toward a European canopy height model. *Earth and Space Science*, 13, e2025EA004544, 20 pp. https://doi.org/10.1029/2025EA004544

Nadir aerial view of the historic Charles Bridge in Prague, Czech Republic.
Credit: PRIMIS.

Czechia

ČÚZK (*Státní správa zeměměřictví a katastru* — State Administration of Land Surveying and Cadastre)[6] is one of the few agencies in this series that has run its processing pipeline entirely in-house from the beginning. That is worth noting: mission planning, GNSS/IMU processing, strip adjustment, classification, and product generation have all been handled internally since the first national campaign in 2010.

That campaign, completed in 2013, used a military Aero L-410 FG aircraft equipped with a Riegl LMS VQ-680 scanner integrated into an IGI LiteMapper 6800 system, at densities of roughly 1.2 to 1.5 points/m² (ppsm). The goal was a nationwide digital terrain model — which it delivered, in the form of DMR 5G (a thinned ground-point cloud in LAZ) and the 5-meter raster DMR 4G. Data are distributed in the national S-JTSK/Krovak coordinate system, with delivery in ETRS89 or WGS84 available on request.

Since 2015, a continuous update programme using a Leica ALS80-CM at 5-6 ppsm has kept priority areas current. A gyroplane platform with a Riegl VUX-240, operational since 2024, adds acquisition flexibility for smaller areas. The in-house pipeline has evolved too: SCOP++ gave way to LAStools and TerraScan (with TerraMatch for strip adjustment), now orchestrated through a Python automation framework that integrates PDAL and GDAL, with metadata stored in PostgreSQL.

Processing, AI, and the next campaign

ČÚZK's approach to AI classification is notably measured. In 2025, the agency evaluated machine-learning classification in both TerraScan and IGN's Myriad3D, and reports inconclusive results at the time of this writing. The tools exist, but the agency has not yet found a workflow that meets its quality standards reliably enough to integrate into production. For the forthcoming campaign, at least one subcontractor plans to use Flai software for AI-assisted classification, which will offer a practical comparison. This is an honest picture of where automated classification stands in a demanding national context.

The new nationwide campaign, running from 2026 to 2029, sets a minimum density of 15 ppsm — a specification driven not by terrain modeling but by a new ambition: a national 3D base model of the built environment, integrating building geometry, transport infrastructure, vegetation, and water bodies. ČÚZK estimates that 12 ppsm is the floor for reliable automated building reconstruction, hence the 15 ppsm specification. For that reconstruction, the agency plans to use Geoflow/Roofer software, with Blender for manual refinement of complex rooftop geometries.

ČÚZK already publishes in ETRS89/EVRS and maintains strict LAS 1.4 compliance. For a pan-European initiative to work, the agency points to what would need to change more broadly: heterogeneous densities and classification schemes, misaligned acquisition epochs, unresolved vertical datum differences, and the need for sustained coordinated funding rather than one-off harmonization efforts.

Norway

Norway completed its National Altitude Model (Nasjonal Detaljert Høydemodell,

6 https://cuzk.gov.cz/

NDH) between 2016 and 2022. The full terrestrial land area is covered. Kartverket[7] now faces the question every agency faces after a nationwide campaign closes: what does a sustainable program look like going forward?

There is no current plan for a centrally funded second nationwide sweep. Instead, approximately 12,000 to 15,000 km^2 are resurveyed annually through Geovekst, a long-standing collaborative framework that pools funding from municipalities, regional authorities, and national agencies. Kartverket is candid that this rate is not sufficient given the climate risks Norway faces — the country's terrain is acutely exposed to flooding, landslides, and coastal change.

The NDH was designed at 2 ppsm, which covered the primary use cases at the time: flood and landslide modeling. Areas with higher demonstrated need could be flown at 5 ppsm under Geovekst co-funding arrangements.

Nearly 50,000 areas are downloaded each year from hoydedata.no, with applications ranging from carbon accounting and biomass estimation to solar analysis, 3D city modeling, game development, and archaeology.

Innovation at the margins

Innovation at Kartverket tends to happen at the research edge rather than in production workflows. The agency participates in EuroSDR R&D projects and has involved master's students in point-cloud classification work, covering both terrestrial and bathymetric lidar data. Image matching has been applied to all aerial image campaigns in Norway since 2021. The agency monitors developments in 3D capture methods, including Gaussian splatting — a neural rendering approach increasingly being explored for geospatial applications — though these remain at the monitoring stage rather than in operational use.

The most substantive forward-looking project is coastal integration: Kartverket is evaluating a seamless terrain model that would combine terrestrial lidar with bathymetric data to produce a continuous elevation surface from mountain to seafloor. The principal obstacle is logistical rather than conceptual. Norway's coastline is extraordinarily long and intricate, and the steep terrain that runs to the water's edge makes aerial acquisition expensive in exactly the areas where it matters most.

On pan-European harmonization, Kartverket's list of obstacles is the most specific of the five countries in this article: update cycle misalignment; divergent vertical and horizontal reference frames with no official transformation between many of them; inconsistent classification standards; data security restrictions; administrative barriers to cross-border sharing; and differences in national priorities and resources. The list is not pessimistic — it is a realistic account of what coordination would actually require.

Poľana Extinct volcano in central Slovakia.
Credit: Úrad geodézie, kartografie a katastra Slovenskej republiky (ÚGKK).

Slovakia

As recently as 2017, Slovakia had no accurate national DTM or DSM. By 2023, it had completed a full nationwide ALS campaign. It is now well into a second.

The Geodesy, Cartography and Cadastre Authority (ÚGKK SR)[8] launched the first campaign in 2017, with scanning completed in 2022 and processing finished the following year. The specified minimum was 5 last-return ppsm. What was actually delivered averaged 30 ppsm — a result ÚGKK attributes directly to how the tender was structured. Rather than awarding on lowest price, the authority used a most-economically-advantageous-tender approach that explicitly scored quality indicators, including point density. Contractors competed

7 https://www.kartverket.no/en

8 https://www.skgeodesy.sk/sk/

on what they could deliver, not just what they were required to. Scanning is carried out during the leaf-off season to maximise ground penetration, since the primary goal of both cycles is a reliable DTM. The result: a specification multiplied sixfold in practice.

For the second cycle, now underway, the minimum has been raised to 15 ppsm — and delivered density is currently averaging 43 ppsm. Priority areas are selected in consultation with the public bodies that use the data, targeting locations where terrain or surface change is likely or has been reported.

ÚGKK outsources acquisition and classification entirely and does not examine the processing methods contractors use — it inspects the delivered products. Point clouds are classified into 10 to 12 ASPRS classes; DTMs and DSMs are generated at 0.5-meter resolution. All products are published as open data under CC-BY.

Archaeology of the invisible. Using special visualization techniques, gold panning sites from the 14th to 18th centuries were discovered near the village of Malinová, Slovakia based on lidar data (left). The intense activity of miners left significant traces. The site is currently covered by dense forest (right).
Credit: ÚGKK.

What the data has revealed

The agency has experimented with LoD 2.0 3D building models but has not moved them into production: automated processing of complex geometries falls short of acceptable quality, and national-scale manual correction is not realistic. That assessment, offered plainly, is itself useful — it reflects where the technology stands for agencies without large in-house processing teams.

3D vector building model in LoD 2.0 from lidar.
Credit: ÚGKK.

Applications include landslide mapping, flood prevention modeling, archaeological prospection, and infrastructure design. Because the data are fully open, ÚGKK has no systematic record of who downloads it. Among the uses it has documented is the identification near Malinová of gold-panning sites dating from the 14th to 18th centuries, found through lidar visualization of forest-covered terrain.

ÚGKK is a member of EuroGeographics. Its view on a pan-European lidar dataset is pragmatic: the existing EuroDEM shows that pan-European elevation data is possible, but quality is uneven. With most European countries either holding or planning high-quality lidar datasets by the end of the decade, the conditions for a more coherent product are gradually taking shape.

Slovenia

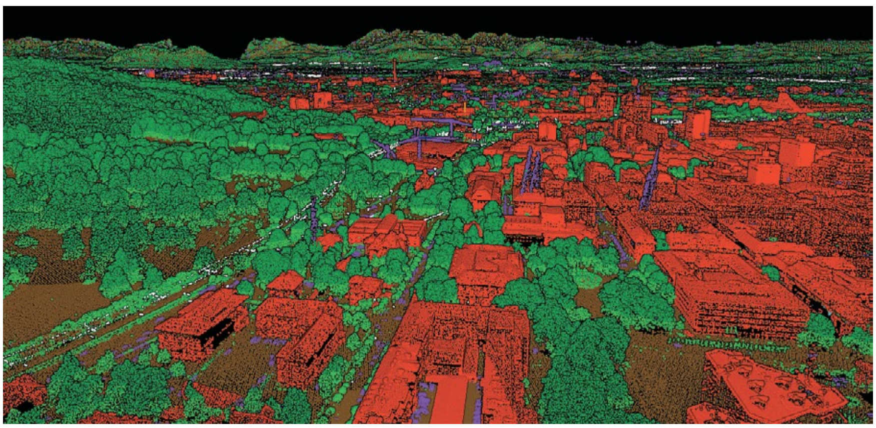
Slovenia has run two distinct national lidar programs, which together bring the country to full national coverage at increasingly useful densities.

The first, the Lidar Scanning of Slovenia (LSS), ran from 2011 to 2015 under the Environment Agency (ARSO) and the Ministry of Environment and Spatial Planning. The country was divided into 19 acquisition blocks. Typical point density was 5 ppsm, with 2 ppsm in mountainous and heavily forested terrain and 10 ppsm in high-risk flood zones — a differentiated specification that reflected the program's primary use case from the outset. Terrain data was available for the whole country by September 2015.

The follow-up — the Cyclic Laser Scanning of Slovenia (CLSS) 2023–2025, managed by the Surveying and Mapping Authority (GURS)[9], has

9 https://www.gov.si/en/state-authorities/bodies-within-ministries/surveying-and-mapping-authority/

Side-by-side comparison of a nadir orthophoto (left) and the corresponding RGB-colorized 3D lidar point cloud (right) capturing the urban fabric of Ljubljana, Slovenia.
Credit: GURS.



An example of a classified aerial lidar point cloud over an urban area in Slovenia. Standardizing these thematic classification schemes across different national datasets remains a key challenge for pan-European data integration.
Credit: GURS.

raised the standard to 10 ppsm nationwide, accompanied by RGBN aerial imagery. Acquisition was carried out in three annual phases, covering one third of the country each year. Distribution is now underway, with data freely accessible through a 3D viewer at clss.si and through the Lidar Slovenia Data Downloader QGIS plugin, in LAZ/LAS and ASC formats. The ARSO portal continues to serve data from the original LSS campaign.

Product outputs include classified point clouds with 13 classes, DTM, DSM, normalised DSM, analytical hillshade, true orthophoto, and infrared orthophoto. A 5-meter Slovenia Elevation Model (DMV 5) is also derived from the lidar data and available for broader use.

Automated extraction and machine learning

GURS is in active production with automated building extraction from the CLSS point cloud — roughly one third of Slovenia has been processed, with the second third in progress. Alongside this, the agency is testing machine learning for updating uncategorized roads from the new data. These are not experimental pilots; they are operational or near-operational workflows, which puts Slovenia in a relatively small group of agencies actively deploying machine learning at the production level.

Slovenia's response to the pan-European question carries a particular institutional weight: GURS's director also serves as president of EuroGeographics, and his answer reflects both roles. The roadmap, in his view, should be federated rather than centralized — built by making national datasets interoperable through harmonized specifications and common reference models, driven by concrete use cases such as climate resilience and risk management. The hurdles span technical, political, and financial domains: differences in acquisition cycles and classification standards, the governance complexity of coordinating many national authorities, and the need for sustained investment not just in acquisition but in ongoing maintenance and service provision.

Sweden

Lantmäteriet[10] began replacing Sweden's 50-meter elevation model with a lidar-based dataset in 2009. By 2019, a near-complete national DTM at approximately 1-meter resolution was in place across roughly 450,000 km^2, with some mountainous areas along the northern, Norwegian border still being finalized.

The current National Height Model combines legacy acquisitions at around 0.5 ppsm (2009–2019) with newer surveys at 1–2 ppsm, updated on a rolling cycle of approximately seven years. These feed into hydrological analysis and 3D urban modeling workflows. A dedicated forest scanning program, Laserdata Skog,

10 https://www.lantmateriet.se/

runs separately to keep the national forest database current — an acknowledgement that terrain data and forest structure data have different update dynamics and different institutional users.

Where innovation happens

Innovation in Sweden tends to be distributed. Lantmäteriet has automated the classification of approximately 40,000 bridges and 3,000–4,000 dams from the national point cloud — operational feature extraction at a scale that requires sustained algorithmic development and quality control. Work is also underway to improve the mapping of surface waters from lidar data. On the 3D side, a new national building specification — NS LOD, structured around CityGML 3.0 — has been developed in collaboration with the Swedish National Board of Housing, Building and Planning, and LoD2 building production is being tested through in-house photogrammetry and municipal partnerships combining lidar data with building footprints.

Beyond the agency's own workflows, the open national dataset has enabled a wide range of downstream applications: flood hazard mapping, forest density characterization, drainage ditch identification, detection of previously unmapped forest roads, and the location of charcoal pits — remnants of historical iron production that are largely invisible to optical sensors but appear clearly in lidar-derived terrain models.

Lantmäteriet's view on pan-European harmonization focuses on two things. Data security is one: the question of how openly accessible high-resolution lidar can be across national jurisdictions is not a purely technical one, and it is not settled. Structural harmonization is the other — differences in classification schemes, data formats, and delivery standards across national providers need to be resolved before a truly interoperable continental product is feasible.

Looking across the series

The national elevation activities of twenty-one countries have been described in these four articles. Some patterns are clear.

Point density has risen almost everywhere. Campaigns that flew at 1 to 2 ppsm a decade ago are being replaced — or are planned to be replaced — by surveys at 10, 15, or 20 ppsm, driven by applications that old-generation data simply cannot support: automated building reconstruction, detailed vegetation structure analysis, and infrastructure inventory. The specification is no longer set by terrain modeling alone.

Open data has quietly become the default. Most agencies in this series now distribute lidar products under open licences.

Almost every agency, asked about pan-European harmonization, gave some version of the same answer: technically feasible in principle, genuinely difficult in practice, but worth doing. The specific obstacles — datum misalignments, security restrictions, inconsistent classification, and funding fragmentation — are well understood. What varies is the timeline each agency imagines and how much of the coordination work it sees as belonging to its mandate.

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Measuring Recovery

How Surveyors Helped Rebuild Western North Carolina After Hurricane Helene

BY DAVID **JONES**

In September 2024, the map of Western North Carolina changed.

Roadways disappeared. River channels shifted. Slopes failed. Bridges that had connected mountain communities for generations were damaged, destroyed or left inaccessible. In some places, the landscape no longer matched the records, drawings or maps that had defined it only days before.

Before Hurricane Helene reached the mountains, Western North Carolina had already experienced days of heavy rainfall. Saturated soil and swollen rivers had primed the region for flooding and landslides. When Helene made landfall in Florida on Sept. 26 as a Category 4 hurricane and tracked inland, it carried an extraordinary amount of moisture into the southern Appalachians.

LiDAR data collected over the Lake Lure project area helped surveyors document terrain and topographic conditions following Hurricane Helene.

Flooding from Hurricane Helene reshaped river channels and surrounding terrain throughout Western North Carolina, requiring surveyors to document conditions that in many locations no longer matched pre-storm mapping.

Within roughly 24 to 36 hours, the storm fundamentally altered the region. Rivers rose to record levels, roads washed away, bridges failed and communities became isolated. Interstate closures along I-40 and I-26 severed major transportation routes, while floodwaters and landslides reshaped the terrain itself.

State estimates placed Hurricane Helene's impact at more than $59 billion in damages and recovery needs. More than 6,000 miles of roads and over 1,000 bridges and culverts were damaged, illustrating both the scale of the disaster and the magnitude of the recovery effort that would follow.

As floodwaters receded, emergency response transitioned into long-term recovery. Recovery begins with assessment. Before roads could be rebuilt, bridges redesigned or utilities restored, engineers first needed accurate existing conditions. Existing plans, previous survey data and historical mapping no longer reflected the reality in the field.

Recovery Starts with Assessment

Construction cannot begin without understanding existing conditions. After Hurricane Helene, establishing those conditions became one of the first and most critical steps in recovery.

Unlike conventional projects where existing conditions are largely known, post-disaster surveys often begin without reliable assumptions about access, terrain or even the condition of existing infrastructure. Roads may no longer exist where mapping indicates, waterways may have shifted, and decades-old survey control may require verification or re-establishment before fieldwork can proceed.

For McKim & Creed's survey teams, the challenge extended well beyond collecting measurements. Project sites were often difficult to access, with damaged roads, unstable slopes, debris-filled corridors and altered waterways creating hazards that required careful planning before fieldwork could begin.

Assessment became as much about planning as measurement.

"Every site presented a different set of challenges," said Chad Burchette, McKim & Creed's Mid-Atlantic Survey Director. "Before we could collect a single point, we had to evaluate how the storm had changed access, identify potential hazards and determine the safest way for our crews to work. That assessment became the foundation for everything that followed."

Before field crews could begin collecting data, McKim & Creed teams evaluated site access, verified whether existing survey control remained usable and determined where new control would need to be established. Each site presented different challenges. Some

Recovery couldn't wait for warmer weather. Just months after Hurricane Helene, McKim & Creed survey crews were in the field establishing the existing conditions needed to advance infrastructure repair and reconstruction.

required coordination with transportation agencies to access damaged corridors, while others demanded careful consideration of unstable embankments, active waterways or ongoing cleanup operations.

Every project required surveyors to evaluate safe access, identify potential hazards and coordinate with owners, engineers and public agencies to determine how and when data could be collected safely. Communication became equally important. Conditions evolved daily, multiple crews often worked simultaneously across numerous sites, and information collected in the field needed to move quickly to design teams responsible for rebuilding critical infrastructure.

Establishing clear communication channels between field personnel, project managers and design teams ensured changing site conditions, access constraints and survey findings could be shared in near real time. This allowed field activities to be adjusted quickly while providing engineers with the information needed to begin design as soon as survey deliverables became available.

Technology also played an essential role. Rather than relying on a single data collection method, McKim & Creed surveyors integrated conventional field surveying with terrestrial LiDAR, airborne LiDAR, hydrographic multibeam surveying and georeferenced imagery to efficiently capture accurate existing conditions while minimizing risk to personnel and reducing unnecessary disturbance to recovering environments.

Three projects completed during the recovery effort illustrate how McKim & Creed applied these approaches to support transportation, rail and utility infrastructure reconstruction.

Rapid Assessment in Challenging Conditions

Among the most visible impacts of Hurricane Helene were the bridges that no longer connected Western North Carolina's communities.

Working for the North Carolina Department of Transportation (NCDOT), McKim & Creed survey teams documented five bridge sites in Buncombe County that had been destroyed or severely damaged by flooding. Engineers needed comprehensive existing conditions information quickly to begin evaluating replacement options, yet reaching many of the sites presented challenges of their own.

Flood-damaged roadways, debris and unstable terrain required deliberate access planning before field crews could safely begin work. At the same time, a one-month project schedule demanded rapid mobilization.

Multiple survey crews were deployed simultaneously across the five bridge locations, allowing data collection to proceed in parallel despite difficult winter conditions that included snow and freezing temperatures. Careful coordination among field teams ensured consistent data collection while maintaining flexibility as site conditions evolved.

The resulting survey data established the foundation engineers needed to begin bridge replacement design, demonstrating how rapid assessment can accelerate infrastructure recovery when time is critical.

Reality Capture at Corridor Scale

While bridge reconstruction focused on individual structures, restoring rail service required understanding an entire transportation corridor.

Following Hurricane Helene, Norfolk Southern initiated repairs along approximately 15 miles of railway between Old Fort and Black Mountain, encompassing 93 individual repair locations affected by flooding, erosion and slope instability.

Damaged bridges, washed-out approaches and unstable terrain were among the conditions McKim & Creed survey teams encountered while documenting five NCDOT bridge sites in Buncombe County following Hurricane Helene.

Rather than treating each location as an independent project, McKim & Creed established a comprehensive survey control network referenced to NC Grid (NAD83) and NAVD88. GPS control, terrestrial scanning targets, and precise level ties created a consistent geospatial framework across all 93 repair locations, allowing designers and contractors to work from the same survey-grade reference throughout the corridor.

Using a RIEGL VZ-600i terrestrial laser scanner, McKim & Creed captured high-resolution three-dimensional point clouds and imagery documenting track alignment, bridges, culverts, drainage infrastructure and surrounding slopes. The data was processed in TopoDOT and MicroStation to extract engineering features, develop digital terrain models and produce base mapping, including breaklines and volumetric calculations to support earthwork verification. Deliverables, including registered LAS point clouds, LiDAR calibration reports and DGN files, provided designers with accurate existing conditions while reducing the need for repeated field visits and supporting efficient coordination throughout reconstruction.

For a project spanning dozens of repair locations, reality capture significantly improved efficiency. Designers, contractors and owners could reference the same survey-grade digital information, reducing uncertainty and supporting coordinated reconstruction efforts across the corridor.

Integrating Geospatial Data for Utility Recovery

Hurricane Helene's impacts extended well beyond transportation infrastructure.

In Lake Lure, flooding completely destroyed the wastewater treatment plant's influent pump station and approximately 4,000 linear feet of the town's century-old sewer system. Additional portions of the system sustained damage during both the storm and subsequent cleanup operations, requiring engineers to rethink significant portions of the utility network.

Capturing existing conditions required a more comprehensive approach than conventional land surveying alone.

Working alongside LaBella Associates, McKim & Creed's survey teams integrated airborne LiDAR, georeferenced shoreline imagery and conventional survey methods to develop a comprehensive dataset supporting the redesign of critical wastewater infrastructure. Previously collected hydrographic survey data for Lake Lure also provided an important pre-storm baseline, allowing project teams to better understand how the landscape had changed and helping inform recovery planning.

Conventional surveying established the project control framework that unified all datasets into a common coordinate system while providing supplemental measurements in areas where additional field verification was required. The team also prepared subdivision and easement plats to support the design of new electrical lines, sewer lines and lift stations.

To document existing shoreline conditions, McKim & Creed captured georeferenced imagery using a vessel-mounted camera system. Delivered through an interactive GIS-enabled viewer, the imagery allowed engineers and stakeholders to virtually navigate the shoreline, assess site conditions and

> "The strength of a multi-platform approach lies not in the individual technologies, but in how they complement one another."

make informed design decisions without repeated field visits.

Airborne LiDAR rapidly documented the project area following a planned 30-foot drawdown of Lake Lure, exposing terrain that would normally remain submerged. Using a RIEGL VQ-1560 II and a PhaseOne IXM-RS150F sensor simultaneous Lidar and imagery were acquired, the survey captured high-density topographic data across approximately eight square miles. The resulting dataset supported detailed planimetric mapping and one-foot contour generation from the water's edge to the 995-foot contour, providing engineers with an accurate representation of post-storm conditions.

"Each technology contributed to a different piece of the puzzle," said Rob Crawshaw, McKim & Creed's Director of Aerial Mapping. "Conventional surveying established the control framework, LiDAR documented the terrain and infrastructure, imagery provided visual context, and our existing hydrographic data offered a valuable pre-storm baseline. Integrating those datasets gave engineers a complete understanding of existing conditions, allowing them to make more informed decisions throughout the recovery process."

Together, these integrated surveying methods—and the ability to compare newly acquired information with existing hydrographic data—provided engineers with the high-resolution geospatial information needed to redesign critical wastewater infrastructure while minimizing environmental disturbance and reducing the need for repeated site access.

More than Measuring

Hurricane Helene reinforced the evolving role of the surveying profession in disaster recovery. As extreme weather events become more frequent and infrastructure systems face increasing demands, surveyors are being called upon not only to document existing conditions, but to establish the geospatial foundation upon which recovery depends.

That responsibility extends beyond collecting accurate measurements. It requires evaluating safe access, coordinating with multidisciplinary teams, selecting the appropriate technologies for each environment and delivering reliable information under compressed schedules. Whether documenting damaged transportation infrastructure, restoring rail corridors or supporting utility reconstruction, surveyors are often among the first technical professionals on site, and among the last whose data continues to inform design and construction.

No single technology solved the challenges presented by Hurricane Helene. Instead, recovery demonstrated the value of integrating conventional surveying with terrestrial and airborne LiDAR, hydrographic surveying and georeferenced imagery to create comprehensive, survey-grade datasets tailored to each project's needs.

The strength of a multi-platform approach lies not in the individual technologies, but in how they complement one another. Conventional surveying establishes the control framework that ties every dataset to a common coordinate system. Airborne LiDAR rapidly captures terrain across large areas, terrestrial LiDAR documents complex infrastructure with exceptional detail, hydrographic surveys provide critical information below the waterline, and georeferenced imagery adds visual context for engineers and stakeholders. When integrated into a unified geospatial model, these datasets provide a more complete representation of existing conditions than any single method could achieve, improving design decisions, reducing repeat field visits and enabling project teams to work from a common source of truth throughout recovery.

Hurricane Helene changed Western North Carolina's landscape in a matter of days. Rebuilding the area will take years. Throughout that process, the surveying profession will continue to provide what every recovery effort depends upon: an accurate understanding of the landscape as it exists today and the geospatial framework needed to design the resilient infrastructure of tomorrow.

David Jones, PLS, CFS, is senior vice president of geomatics at McKim & Creed. A professional land surveyor and certified floodplain surveyor, he has more than 40 years of experience leading complex surveying, hydrographic and reality capture initiatives, with expertise in applying integrated geospatial technologies to support infrastructure planning, disaster recovery and water resource management.

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Agentic AI can handle repetitive, time-consuming steps, such as QC, feature extraction, catalog search, flight planning, SLAM processing and more. But experts will still need to guide interpretation, validate outputs and refine custom tools.

We call this human-in-the-loop GeoAI. Analysts can author specialized workflows, then let the system operationalize them at scale. Non-experts gain conversational access to complex geospatial data, but experts remain essential for context, nuance and quality.

Q: For lidar-heavy organizations, where does GeoAI deliver the fastest ROI?
Vincent: Anywhere you have massive volumes of data and repetitive analysis.

The biggest early wins we see include:

- Quality assurance (QA) and QC on incoming lidar and imagery
- Asset inventory and feature extraction
- Sorting and triaging large imagery collections
- Coordinating multi-sensor workflows

ROI shows up in hours reclaimed, which frees analysts to focus on high-value work. When you factor in analyst wages, project load and throughput, compressing a 60-minute workflow into a few minutes isn't just convenient; it's transformative.

Q: You've emphasized the difference between "models" and "workflows." Why is that distinction so important?
Vincent: Models are powerful, but a model by itself is still only one component of an operational workflow. They classify, detect or segment. Workflows are where enterprise value lives. A workflow understands which data to trust, which tools to run and in what order, and where results need to go.

That's the power of agentic AI. It connects models to business processes.

Q: NV5 often describes its generative AI solution GeoAgent™ as "technology agnostic." Why is that important for lidar and sensing teams?
Vincent: Because no organization wants to abandon the ecosystems they already trust. Our approach is to ensure that generative AI can integrate with ArcGIS, Trimble Unity, Planetary Computer, our ENVI image processing and analysis solution, and more. We don't want AI to replace your existing stack, we want it to orchestrate across it. That orchestration carries the data, parameters and geospatial context needed to coordinate each step across the different systems.

This matters for lidar because workflows rarely live in one place. You may process point clouds in one place, manage assets and visualize results in other systems, and store data in cloud catalogs. A technology-agnostic generative AI agent ensures results flow seamlessly from analysis to action.

Q: How is agentic AI changing lidar and remote sensing today?
Vincent: Agentic AI is starting to change the parts of lidar and remote sensing workflows that sit around the model or tool itself. A lot of AI discussion has focused on classification or feature extraction, but the more operationally challenging issues typically center around:

- Which dataset is the right one?
- Does it cover the area of interest?
- Is it current enough?
- What processing path should be used?
- What parameters are safe?
- Where should the output go once it is created?

A GeoAI agent can help turn that into a repeatable workflow instead of a series of manual handoffs. For lidar, that could mean finding the right point cloud or derived surface, checking coverage and metadata, running the appropriate processing step, comparing against prior conditions, and producing a reviewable layer or summary.

Q: How will agentic AI change how geospatial analysts work in the future?
Vincent: I think the analyst role will move closer to workflow direction and review. The analyst still owns the judgment, especially in lidar where quality, classification, density, collection conditions and local context matter. The difference is that the analyst should not have to manually rebuild the same path every time.

A good agentic workflow can propose the data, run the first-pass analysis, expose the steps it took and stop at review points before anything becomes authoritative. Human-in-the-loop should mean practical review gates, including:

- Approving the input data and the tool path
- Inspecting flagged areas
- Adjusting thresholds
- Deciding whether the output is good enough to publish or send downstream

Q: What workflows are possible today that weren't realistic even two years ago?
Vincent: The realistic change is chaining remote sensing, GIS and delivery into one workflow from a plain-language request. For example: "Show me where this corridor changed since the last collection and which assets need review."

Today that request can be broken into executable steps: identify the area of interest, find the relevant lidar or imagery, clip the data, run change or classification logic, intersect the result with asset layers, and publish a map layer or report for review.

Two years ago, each of those pieces existed somewhere, but making them work together usually required a custom script. The newer opportunity is making that pattern repeatable across projects without pretending the agent is the expert. The agent handles the orchestration. The analyst handles the judgment.

Q: Looking ahead, what excites you most about what lies ahead for agentic AI in geospatial in the next two, five, even 10 years?

Vincent: In the near term, I'm most excited about practical, repeatable workflows that save real time without overpromising autonomy. In five years, I think the bigger shift is cross-system geospatial work where remote sensing data, GIS layers, asset systems and reporting tools can be connected through the same workflow.

Looking ahead 10 years, I believe the most interesting outcome will be persistent geospatial understanding: systems that track what was collected, what changed, what was reviewed and what still needs attention. Lidar and remote sensing data should become part of a living operational picture that can be questioned, updated and acted on as conditions change.

Chancee Vincent is Principal AI Architect at NV5, where he leads the development of enterprise-grade geospatial AI and agentic systems that help organizations transform complex geospatial data into actionable intelligence. Drawing on more than a decade of experience in geospatial intelligence, GIS and advanced imagery analysis (including support for U.S. Special Operations Forces and the National Geospatial-Intelligence Agency) Chancee specializes in integrating AI into operational workflows. His work focuses on building scalable, secure GeoAI solutions that accelerate decision making across government and commercial organizations.

GeoAI in Practice

A Conversation with NV5's Chancee Vincent

Agentic AI is reshaping how organizations collect, process and act on geospatial data. But while the hype is everywhere, operational adoption remains elusive for many. *LIDAR Magazine* spoke with Chancee Vincent, principal AI architect at NV5, about where organizations really are in their AI journey, why agentic workflows matter and models alone are not enough, and how GeoAI will transform lidar and remote sensing over the next decade.

Q: Many organizations are experimenting with AI, but few have operationalized it. From your vantage point, where do geospatial teams stand with regard to their AI maturity today?

Vincent: Most organizations are still in the pilot phase. They've tested models, run proofs of concept, maybe automated a task or two. But moving from experimentation to operational intelligence is where things stall.

The challenge isn't enthusiasm, it's workflow integration. Geospatial teams often have strong tools, but they live in silos. Analysts still spend hours stitching together datasets, running quality control (QC), harmonizing schemas and pushing results into downstream systems. AI pilots may solve an individual task, but often do not address the broader workflow around it.

Operational GeoAI often requires reasoning, orchestration and cross-platform interoperability. To deliver the most value, geospatial agentic AI must understand intent, select the right tools and execute multi-step workflows across imagery, lidar, GIS and operational systems. That's the maturity gap most organizations are trying to cross.

Q: What makes that leap from pilot to production so difficult for organizations?

Vincent: There are two key things: complexity and expectations.

Geospatial workflows are inherently multi-step: Find the right data and validate it, run the right analysis and interpret results, then push them into operational systems. Traditional AI focuses on models. But organizations don't invest in AI because they want a new model, they invest because they want better decisions.

That's why NV5 emphasizes workflow intelligence. The value isn't just in a classifier or a model; it's in connecting AI to enterprise systems, business processes and analyst workflows to deliver actionable insights quickly and easily.

This is why we developed the GeoAI Acceleration Program, which provides a structured path to help organizations assess readiness, prepare data, deploy workflows and maintain AI operations. Without that type of foundation, AI adoption becomes a series of disconnected experiments.

Q: Geospatial professionals often ask whether AI will replace human expertise. How do you address that concern?

Vincent: AI isn't replacing geospatial experts, it's augmenting their work and freeing them up to do more high-value work.

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