Rockfall Source Identification and Risk Assessment at the Caldera of Santorini Island, Greece, based on Aerial LiDAR Data

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The unpredictability of rockfalls, the complexity of their triggering mechanisms, and the numerous factors influencing their paths make their analysis particularly challenging, especially in the aftermath of the Santorini-Anydros seismic sequence during February 2025.

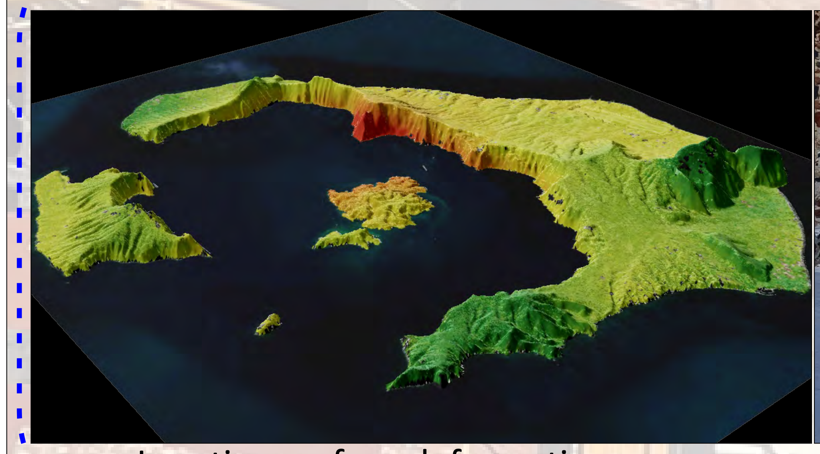
Effective rockfall risk assessment necessitates comprehensive data collection and interdisciplinary approaches for detailed analysis and accurate interpretation. The initial part of the described methodology is based on earth observation data processing for detecting the locations of surface changes, yielding the areas that need higher accuracy observations and detailed measurements. The precision of these interpretations is secured by employing datasets gathered from Light Detection and Range (LiDAR) sensors mounted on aerial platforms, such as unmanned aerial vehicles (UAVs).

A LiDAR sensor employs advanced laser echo technologies to penetrate ground vegetation, regardless of lighting conditions. LiDAR has a natural advantage in surveying regions covered with vegetation since it can partially penetrate the canopy to acquire information about the earth's surface itself. Due to this LiDAR specification, this type of sensor is ideal for outcrops covered by medium density vegetation and therefore essential for not confusing the canopy of small bushes and trees with fallen boulders. By utilizing several filtering algorithms, it accurately detects and classifies ground features, producing extremely precise elevation data. This makes LiDAR point cloud acquisition an essential technique for determining the exact location and key characteristics of rockfalls -among other earth surface deformations- especially for rockfall back analysis, as well as for change detection through multi-temporal surveys.

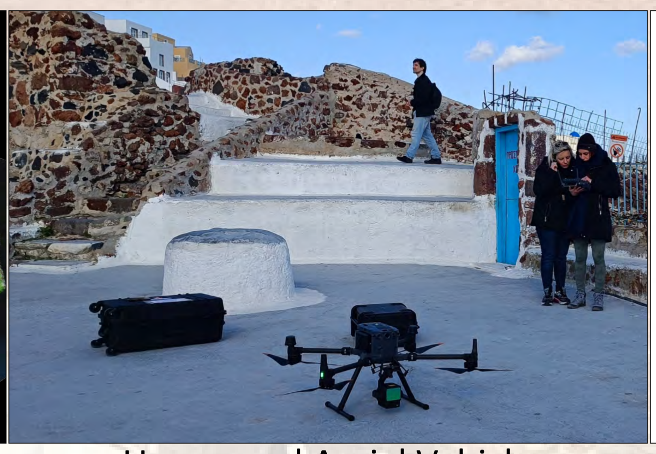
However, UAV LiDAR surveys have certain limitations, including Network-RTK signal loss, which can cause decrease of the UAV accurate location during the data acquisition, not to mention increased sensitivity to meteorological conditions, which can cause laser beam scattering.

During the Santorini-Anydros paroxysmal seismic earthquake sequence of February 2025, during which more than 20,000 earthquakes were recorded, several LiDAR point clouds were collected by a laser scanning system deployed on an Unmanned Aerial Vehicle flying at various altitudes and flight plans, above the steep slopes of Santorini caldera. These are: (i) Ammoudi bay, (ii) Armeni bay, (iii) Thira Old Harbour, (iv) Athinios New Harbour and (v) Korfos bay at Therasia Island.

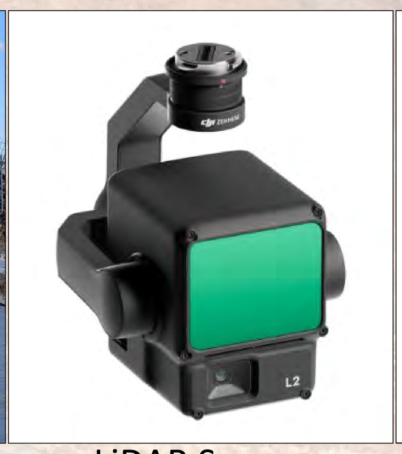
Equipment & workflow



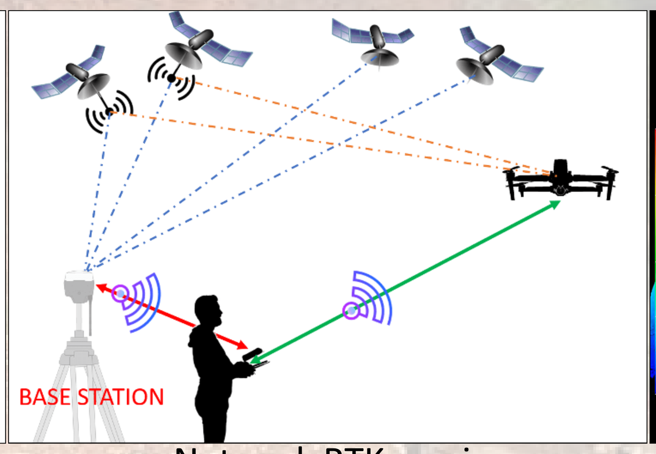
Locating surface deformation areas (SAR data processing)



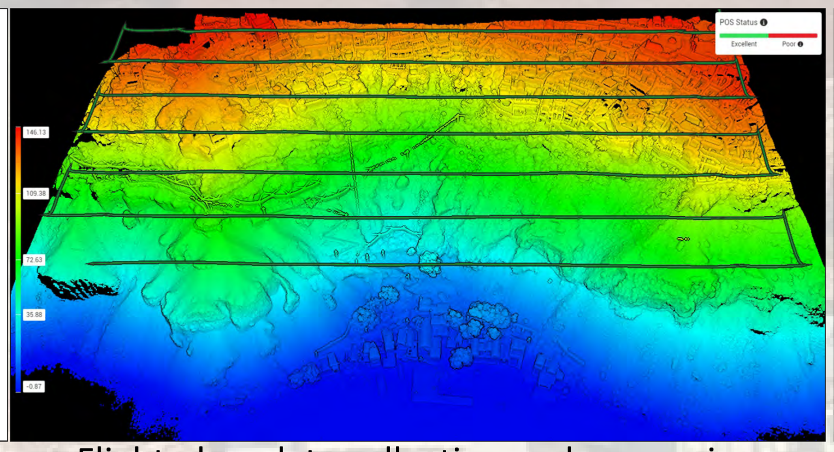
Unmanned Aerial Vehicle (DJI Matrice 350)



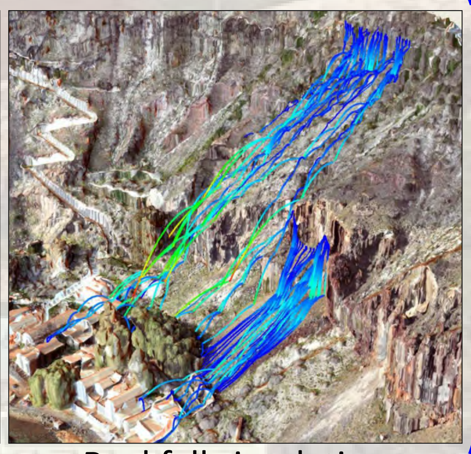
LiDAR Sensor (Zenmuse L2)



Network RTK service (increased geolocation)



Flight plan, data collection and processing (point clouds and RGB images)



Rockfall simulation in 3 dimensions

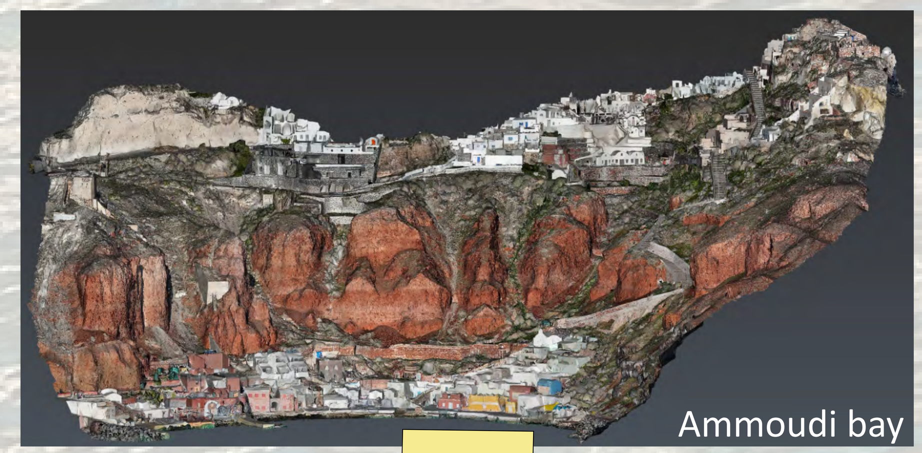
Results & Simulations

Five ultra-high-resolution models were developed to represent the areas of highest risk, focusing on the identification of hanging rocks along the caldera slopes. These models, together with the mapped rock locations, served as input for rockfall simulations. Using the “RocFall3” software, various parameters were tested to simulate rockfall behavior restitution coefficientsFriction Angle). As a result, the rockfall trajectories were delineated, and key outputs such as Kinetic Energy and Translational and Rotational Velocities were calculated for each simulated event.

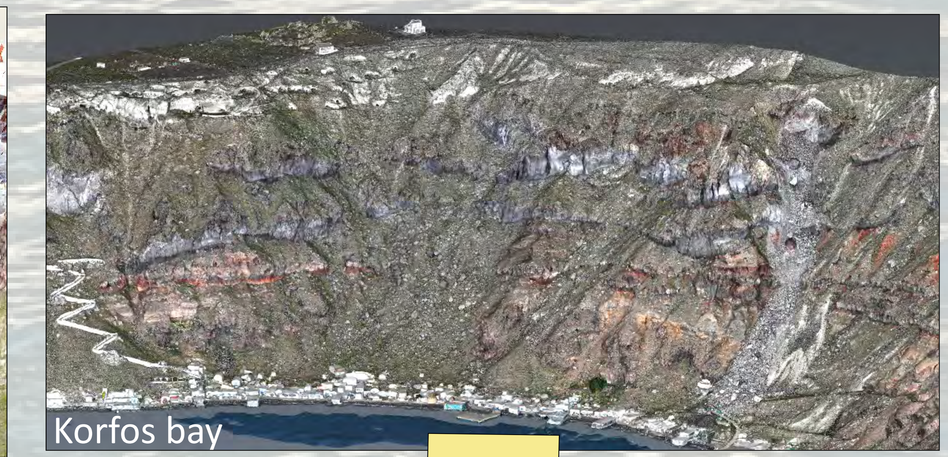
Thira Old Harbour

Armeni bay

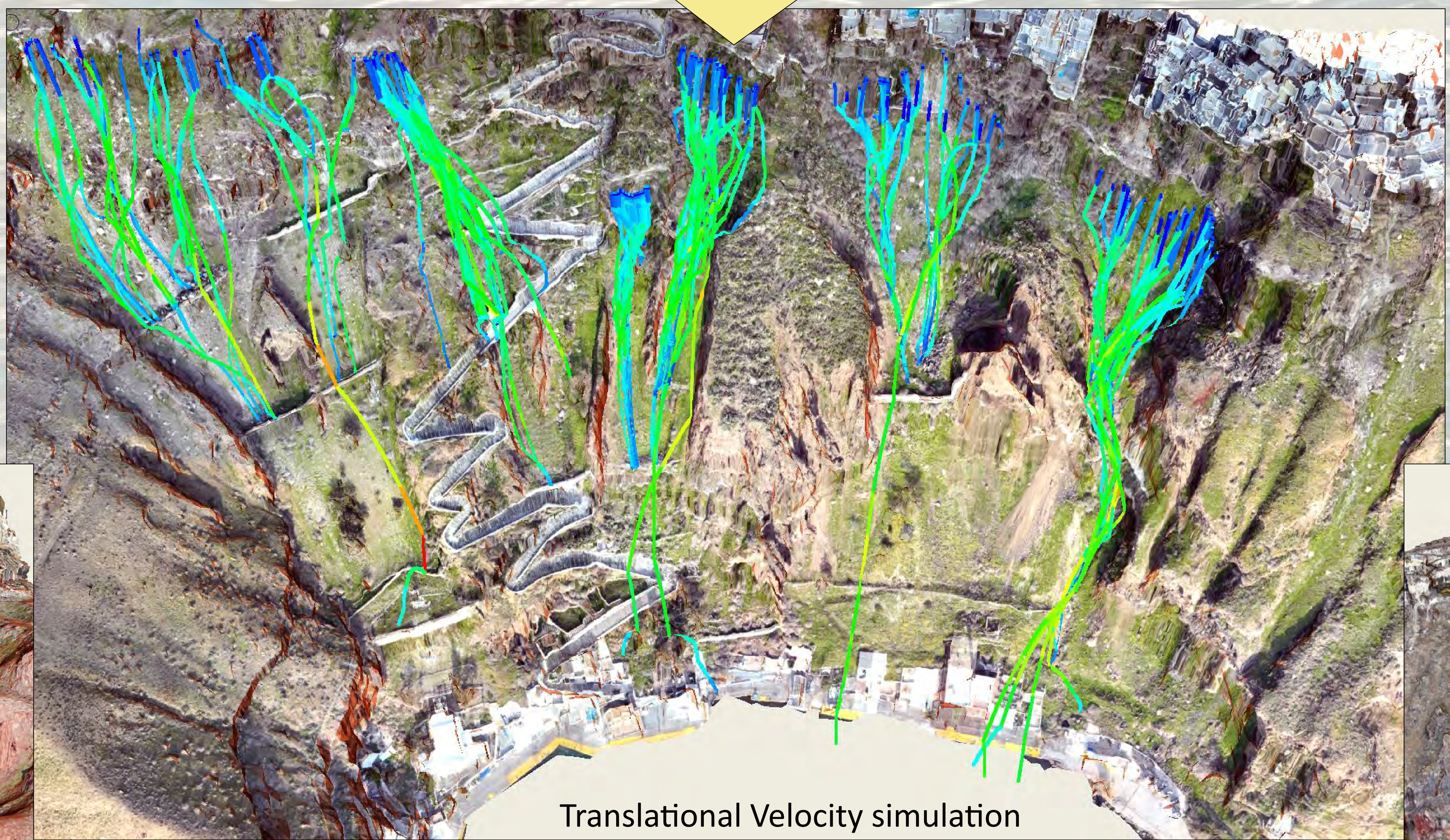
Athinios New Harbour



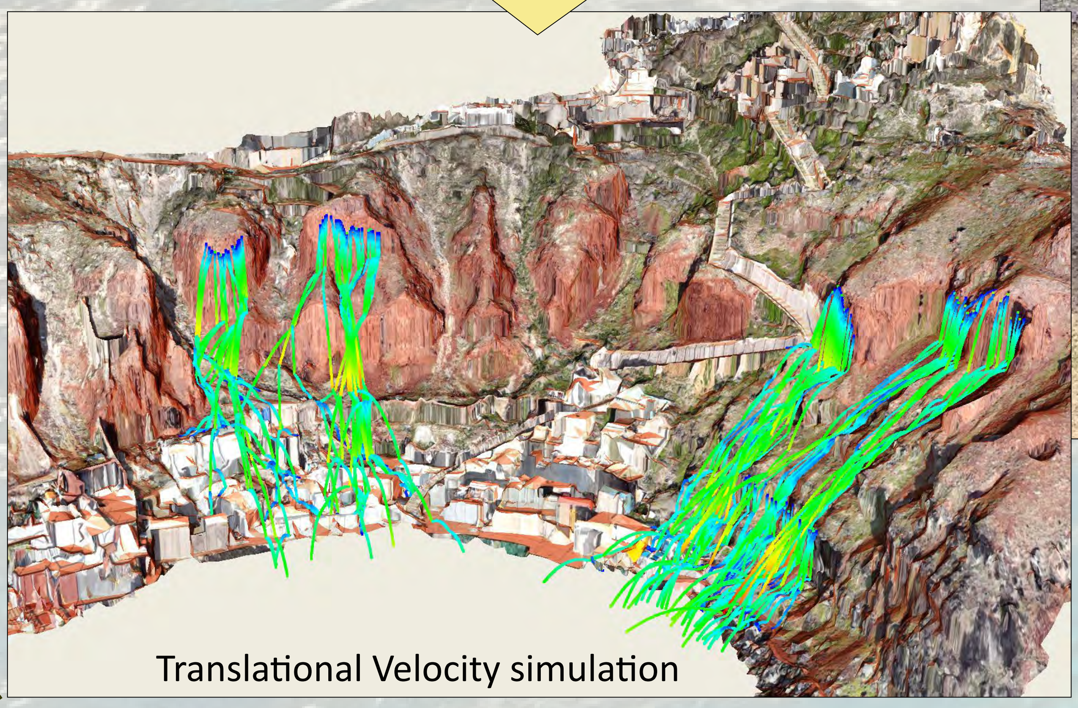
Ammoudi bay



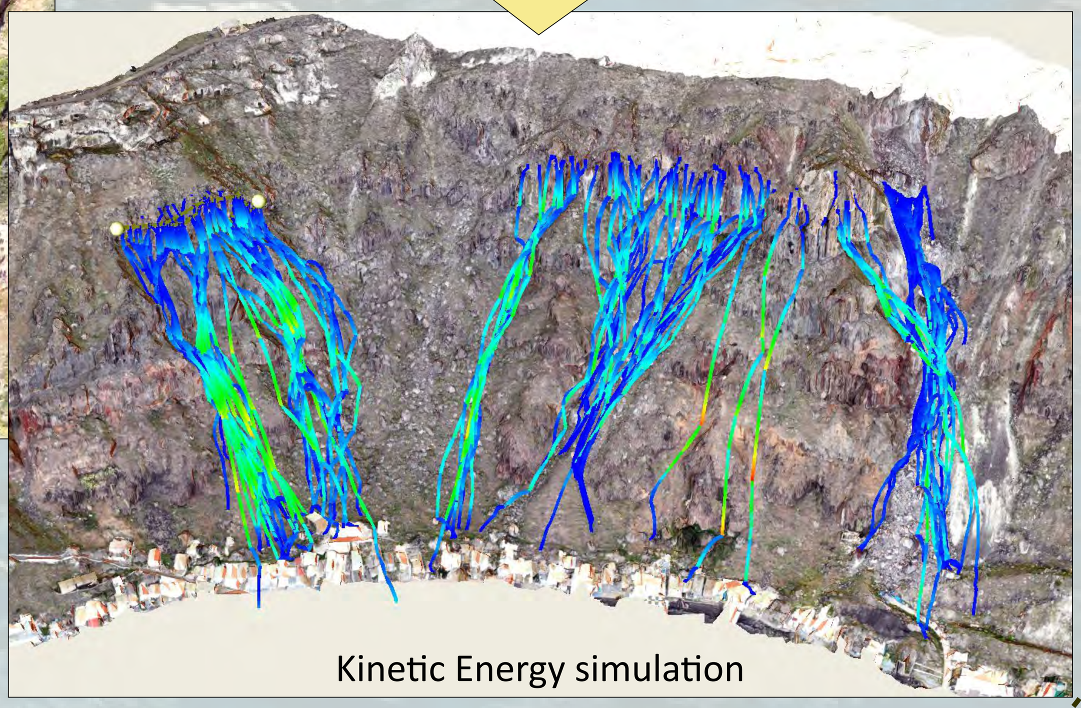
Korfos bay



Translational Velocity simulation



Translational Velocity simulation



Kinetic Energy simulation

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