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FEMME 2026

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📍 Genoa, Italy



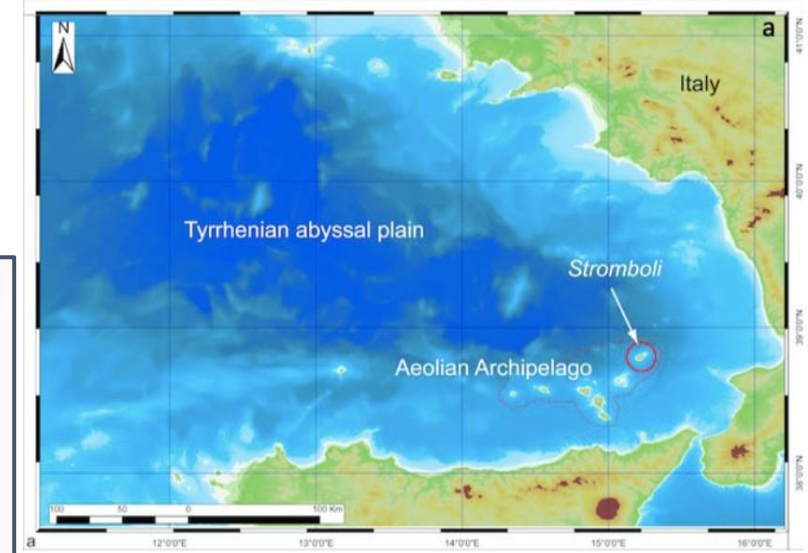
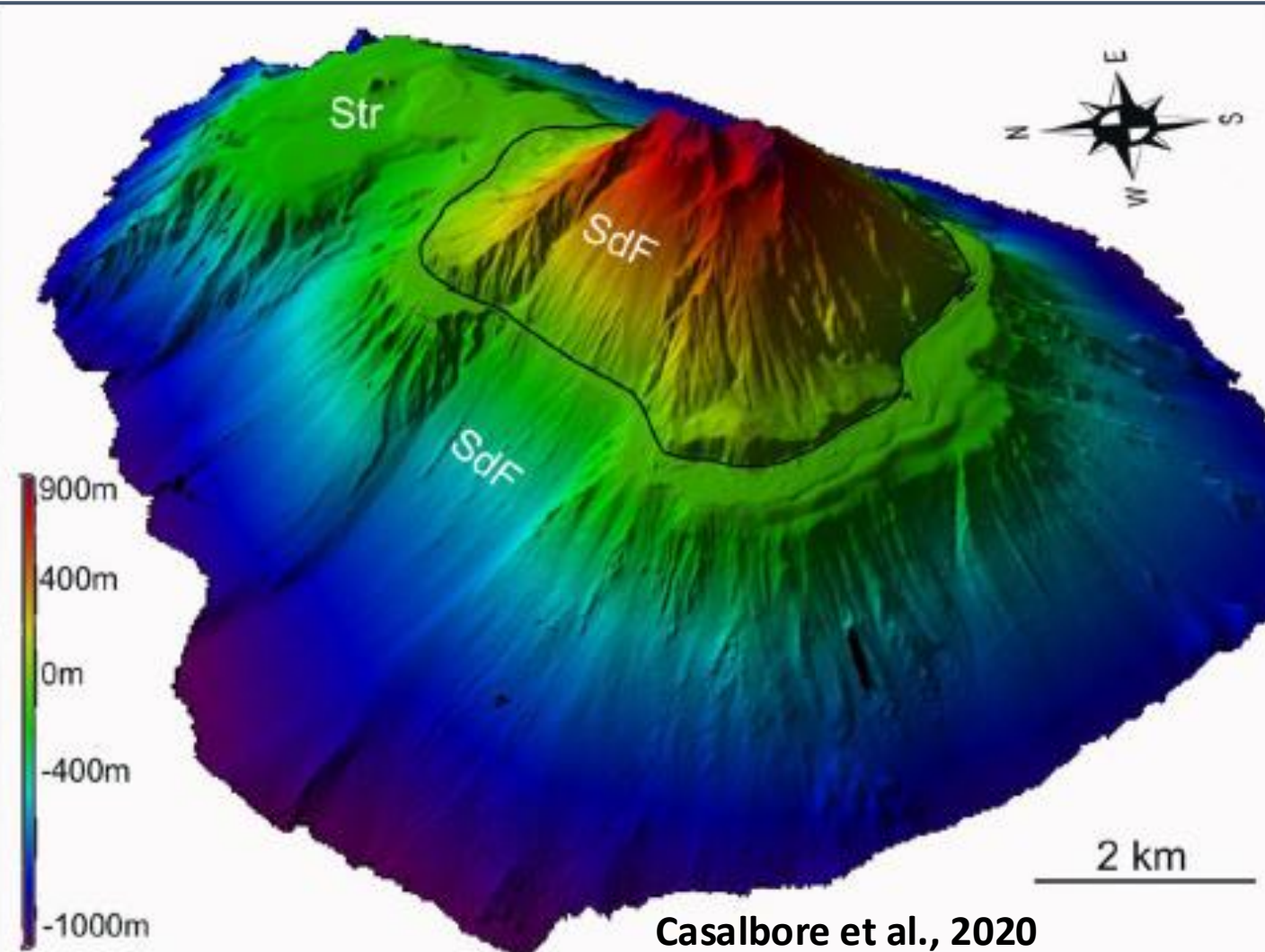
Monitoring of the submarine portion of Sciara del Fuoco (Stromboli) by using an USV (Unmanned Surface Vehicle)

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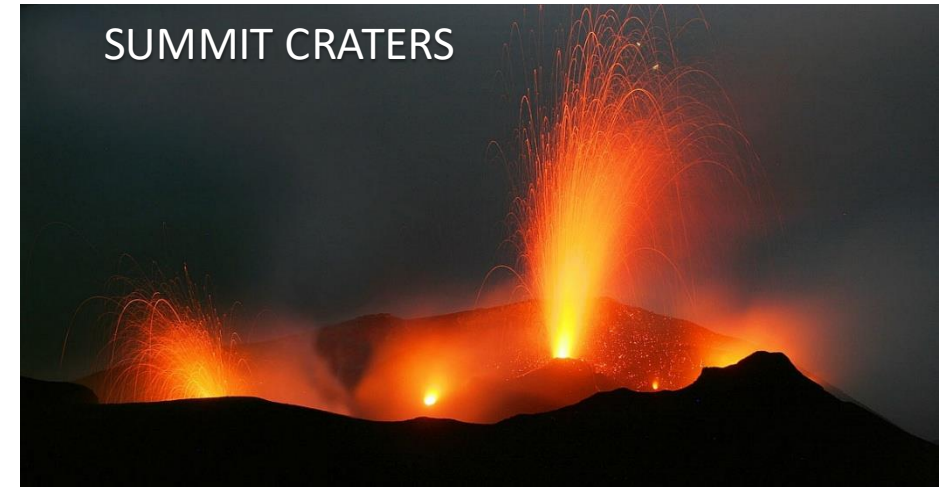
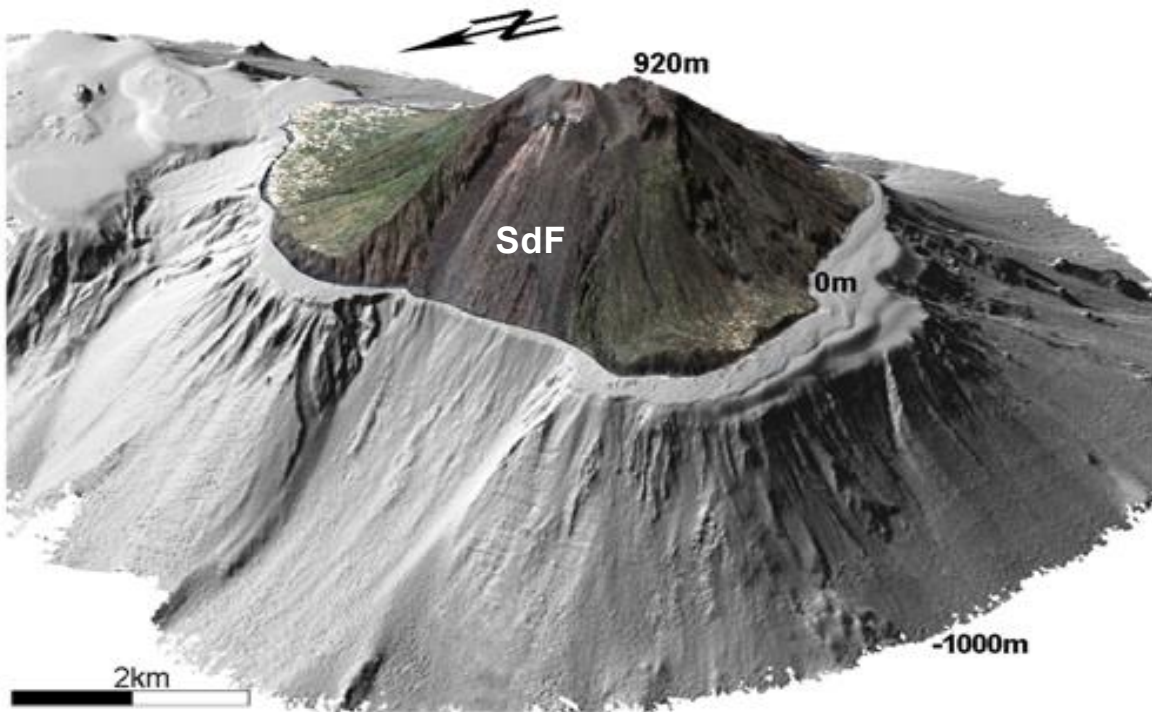
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STROMBOLI



- **Stromboli Island** (924 m asl) is the subaerial portion of a volcanic edifice about 3000 m high, located in the Southern Tyrrhenian Sea (Italy).
- It is a **stratovolcano** and considered an open conduit volcano.
- Its northwestern flank is incised by a very steep, horseshoe-shaped depression, the **Sciara del Fuoco** (SdF), formed about 5 ka ago as a consequence of a flank collapse.

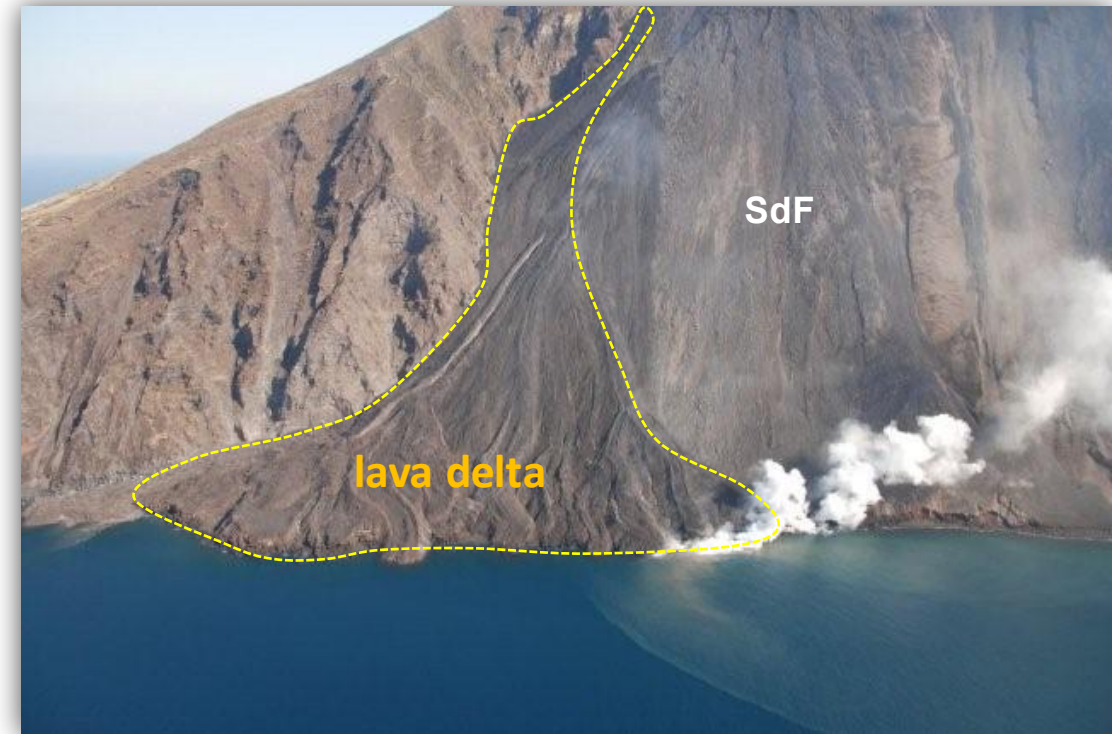


- Sciara del Fuoco (SdF) develops, in perfect continuity between the subaerial and submerged portions, from an elevation of 750 m down to a depth of 700 m.
- It acts as the main pathway for the pyroclastic deposits generated by the summit craters during the persistent explosive activity of the volcano (called **Strombolian activity**) and the occasional lava flows emitted either from the summit craters or from lateral vents during the effusive activity.





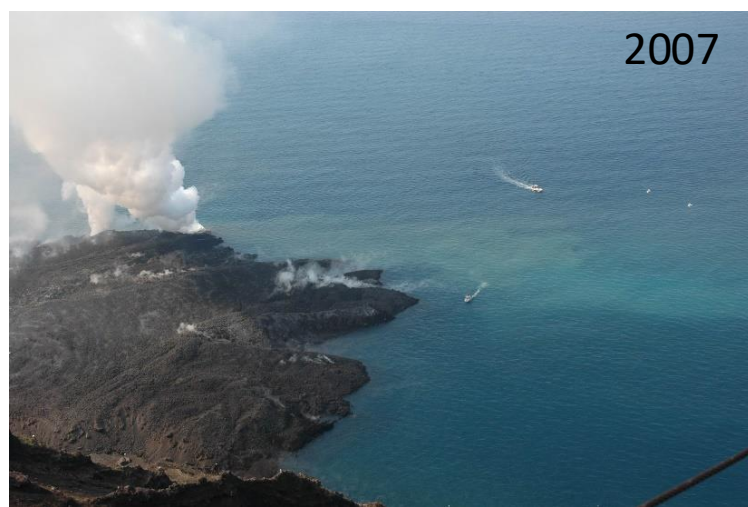
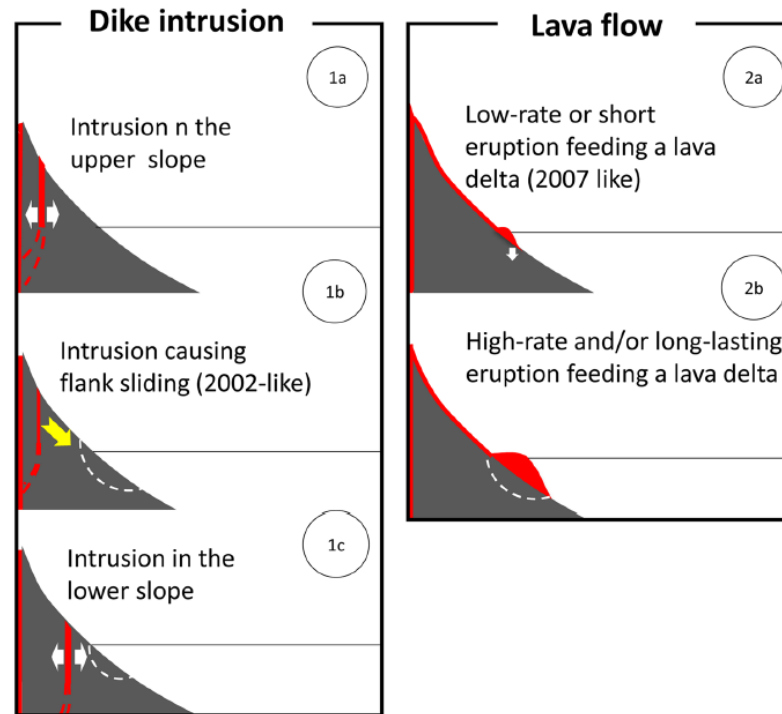
- Both the subaerial and submarine portions of the SdF are characterized by rapid geomorphological evolution and are highly prone to **gravitational instability**.
- The instability results from the interplay between volcanic and depositional processes, including: (i) deformation induced by dike intrusions, (ii) progressive accumulation of volcanic products (pyroclastic deposits and lava flows), which form **unstable debris aprons and lava deltas** in the nearshore environment.

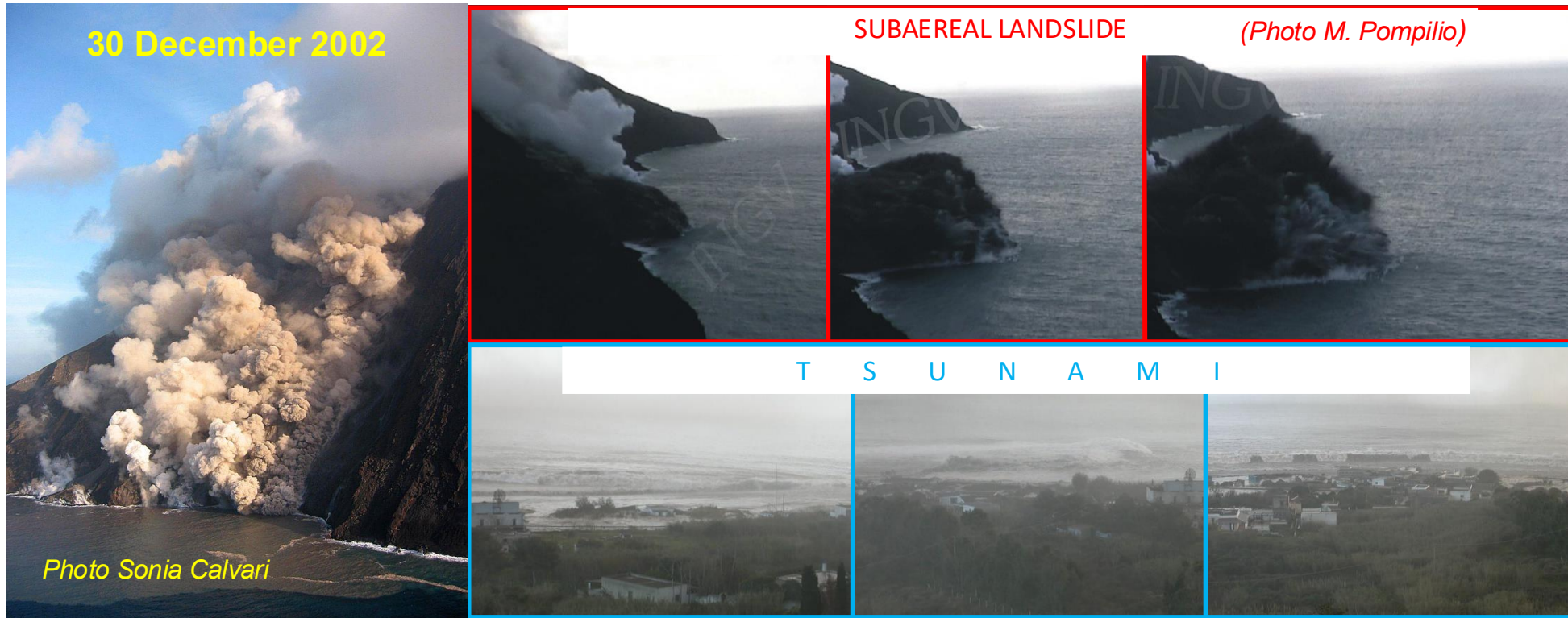


Main scientific goals and applications:

Monitoring the gravitational instability of the submarine sector of Sciara del Fuoco

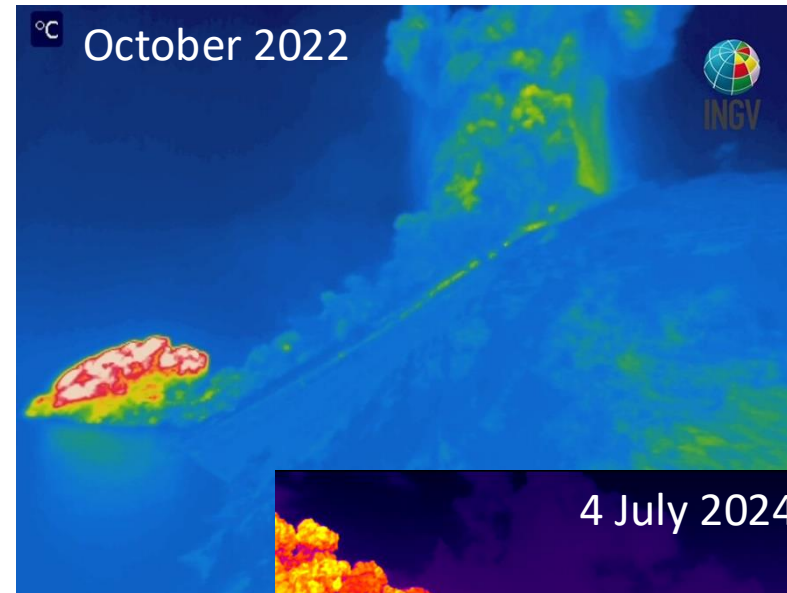
- Dikes intrusion triggering flank sliding (2002)
- Over-accumulation of volcanic products (pyroclastics and/or lava flows) forming weak aprons or **lava deltas** in the nearshore (2007, 2014, 2024, 2026)





The gravitational instability can culminate in mass-wasting events, such as the 30 December 2002 landslide, which was triggered by failure of the submarine sector of the SdF involving an estimated volume of about 24 Mm³ of material (Chiocci et al., 2008), generating a tsunami that propagated around Stromboli and affected nearby islands.

In the last **7 years** Sdf was affected by **several pyroclastic density currents, PDCs**, (four of which in July 2024) either in concomitance of not-ordinary explosive activity (paroxysms of summer 2019 and July 11th 2024 and several major explosions) and effusive activity (due to massive overflows from the summit craters (October 2022) or opening of lateral vents along SdF (July 2024)).



Some PDCs extended up to 1 km offshore. As a consequence, **navigation within 2 miles of the SdF coastline is prohibited.**



UNO

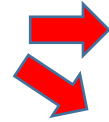
UNDERSTANDING THE ORDINARY TO FORECAST
THE EXTRAORDINARY: AN INTEGRATED APPROACH
FOR STUDYING AND INTERPRETING THE EXPLOSIVE
ACTIVITY AT STROMBOLI VOLCANO

INGV Project 'Rete Multiparametrica'



Main scientific goals and applications

Setting of a **monitoring system** aimed to identify possible morphological changes along the submarine sector of **Sciara del Fuoco** and study its stability in correlation with the subaerial morphological modifications and with changes in the volcanic activity.



INGV - Centro Monitoraggio Eolie

Rete Multiparametrica project (INGV)

HR MDTMs
(Marine Digital
Terrain Model)



Differential maps obtained by comparing multibeam bathymetries acquired pre- and post-event

ONSHORE-OFFSHORE slope maps

- Monitoring of the morphological evolution of **landslide** features, **lava deltas** and **depositional aprons**
- Modelling **tsunami scenarios** off Italian coasts by nearshore bathymetry mapping **(INGV-CAT)**

The best solution to acquire HR multibeam data in **potentially dangerous areas** such as the nearshore sector off SdF.



Safety of the researchers



USV (unmanned surface vessel)
equipped with HR MBES



The **Otter** USV (Unmanned Surface Vehicle)
by Maritime Robotics



This USV is an hydrographic survey tool for high resolution bathymetric surveys in sheltered and enclosed waters.



- Dimensions: 200 (L) x 108 (W) x 106.5 (H) cm (Catamaran)
- Weight: about 100 kg (including MBES and 4 batteries)
- It can be disassembled into smaller components



easily transport and handling

Otter USV is driven by two electrical thrusters that are powered by up to four powerful and easily interchangeable batteries.

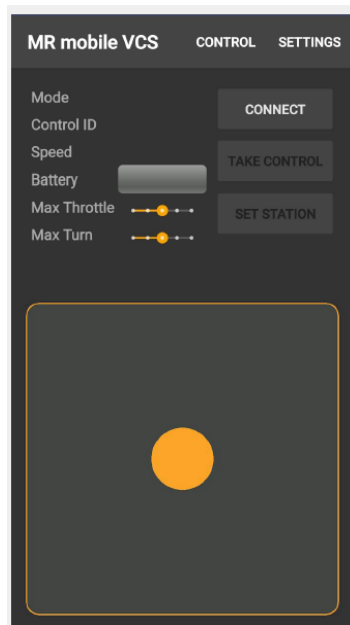


Duration: up to 20 hours at 2 kts;
9 hours at 3 kts.

The Otter is remote controlled by a Vehicle Control Station (VCS) over Linux PC or Android app through:
⇒ wi-fi (range 200 m) ⇒ Long range Broadband PtP Radio (Ubiquiti) (range 2000 m) ⇒ 4G (virtually no limit).

The operator can easily plan missions consisting of individual waypoints, routes, areas or use templates for creating common patterns (offshore SdF).

Live monitoring and visualization of sensor data parameters (Multi-beam quality data, swath width, coverage area) are provided in VCS through SeaCapture software and sensor parameters can be adjusted in VCS as well.



It represents the best compromise between cost, transportability and data quality



Perfect for frequent autonomous seafloor mapping surveys



Data acquisition in repeated surveys

The Otter is equipped with:

➤ **HR Multibeam EcoSounder Kongsberg EM2040P:**

- Frequency range: 200-700 kHz
- Depth range: 0 – 550 m
- 1024 beams per ping (dual swath)
- Beamwidth: 0.6° (700 kHz)
- Swath coverage sector: up to 170°
- Integrated Sound Velocity Sensor (AML SVS)
- Multi Frequency Backscatter (5 frequencies in a single pass)
- Display and storage of water column acoustic data
- Roll, pitch and yaw stabilization ($\pm 15^\circ$)

➤ **Kongsberg Seapath Inertial Navigations System**

- Multifrequency GNSS receiver with RTK correction
- Dual antenna for precise heading computation (0.1°)
- Tactical grade IMU (Roll & Pitch 0.03°)

➤ **Data communication system and remote guidance:**

Wi-Fi, 4G, RF (UHF)

➤ **Autocast SVP winch (100 m)**

➤ **Sound Velocity Profiler:** AML 3 Hydro SVP 500

➤ **HR frontal camera**

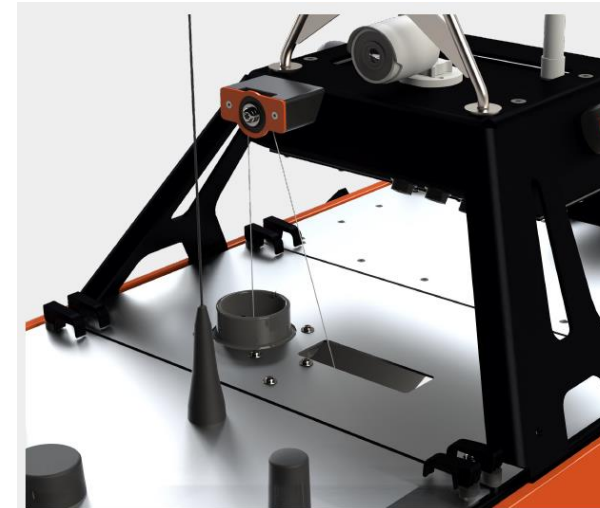
➤ **AIS receiver**



Kongsberg EM2040P



KONGSBERG

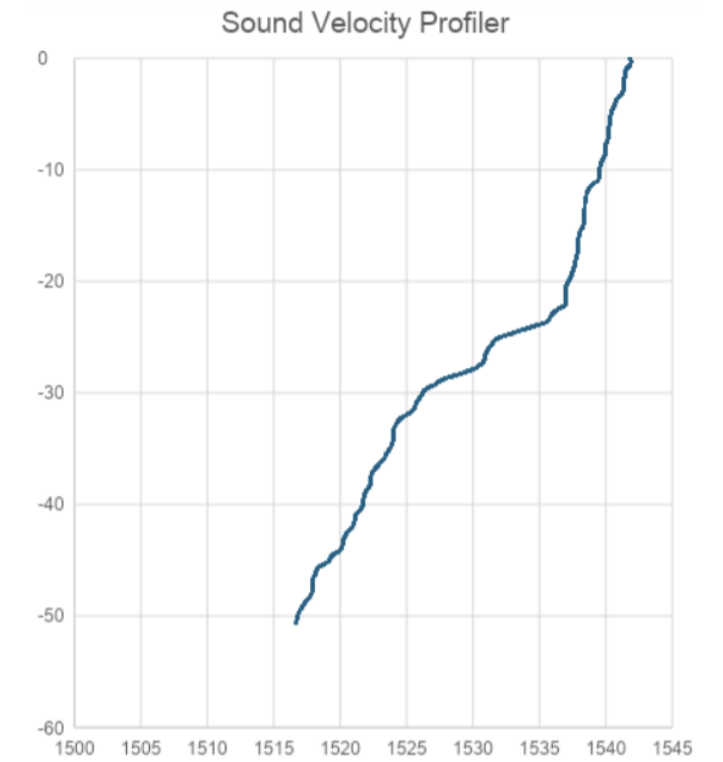


Autocast SVP winch



Sound Velocity Profiler

AutoCast Winch Sound Velocity Profiler AML 3 Hydro SVP 500

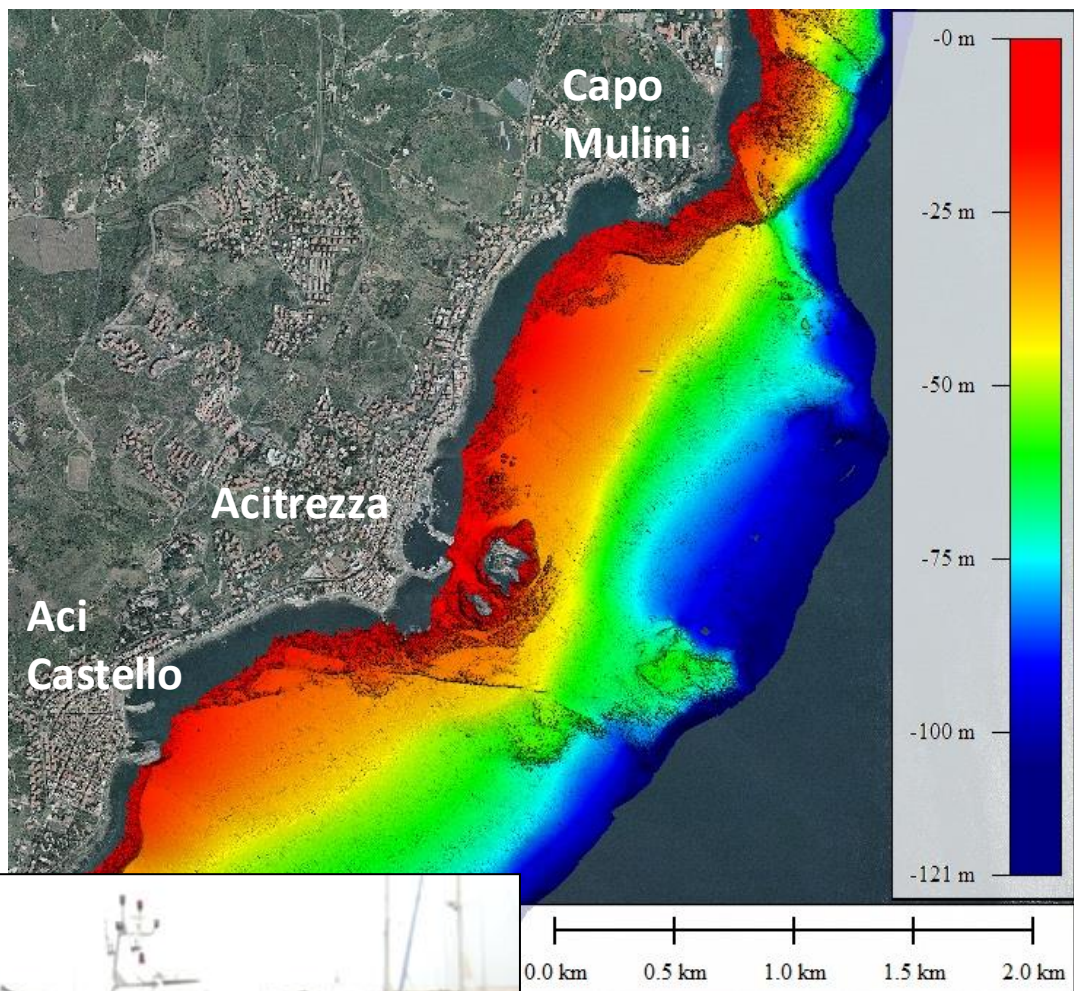


Other scientific goals and applications

- Monitoring submarine **hydrothermal vents** by identifying gas/plume emissions through *backscatter water-column acoustic* data (Panarea, Vulcano, Campi Flegrei)
- Study of **seabed features (texture, hardness and nature)** through the analysis of the *seafloor backscatter data (reflectivity)*

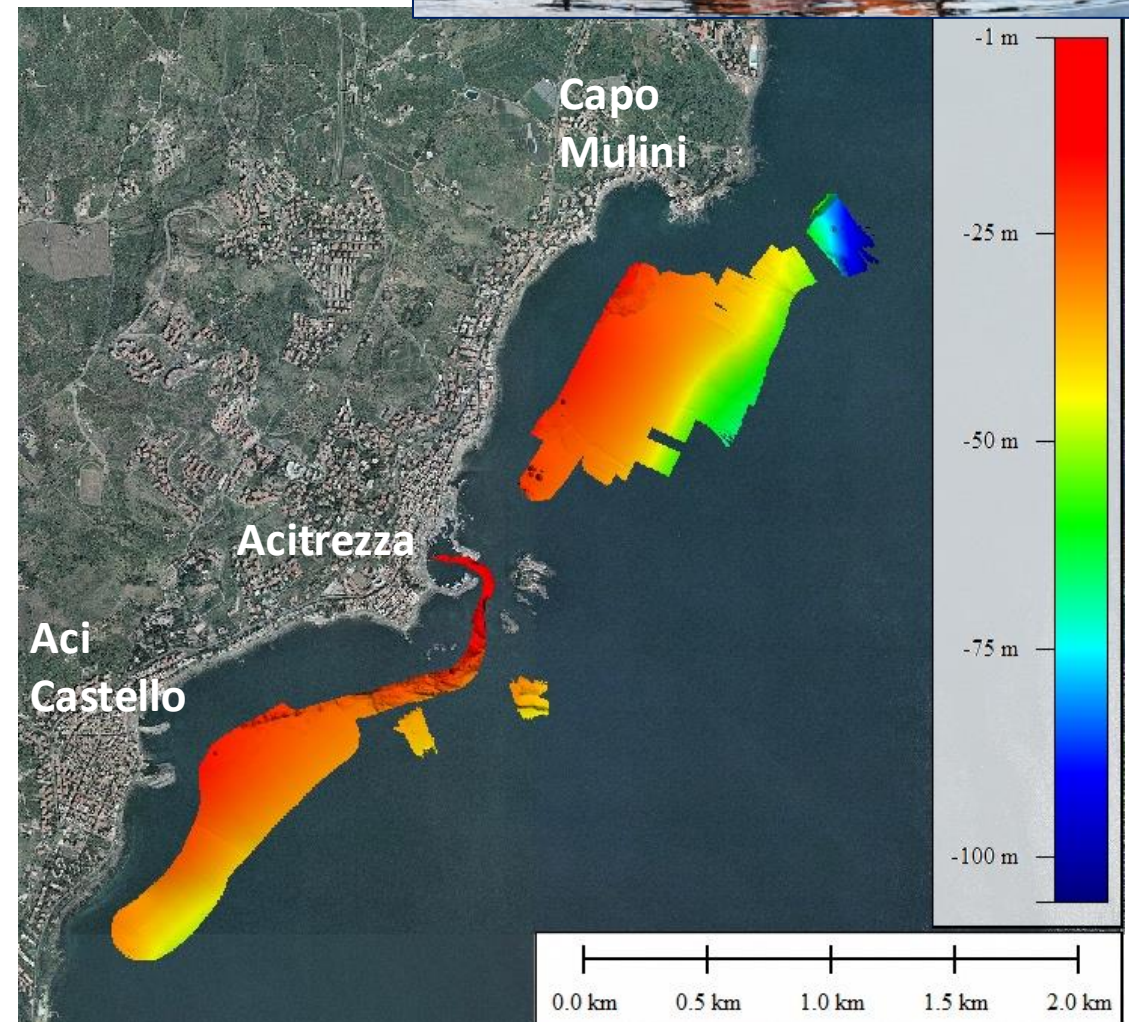


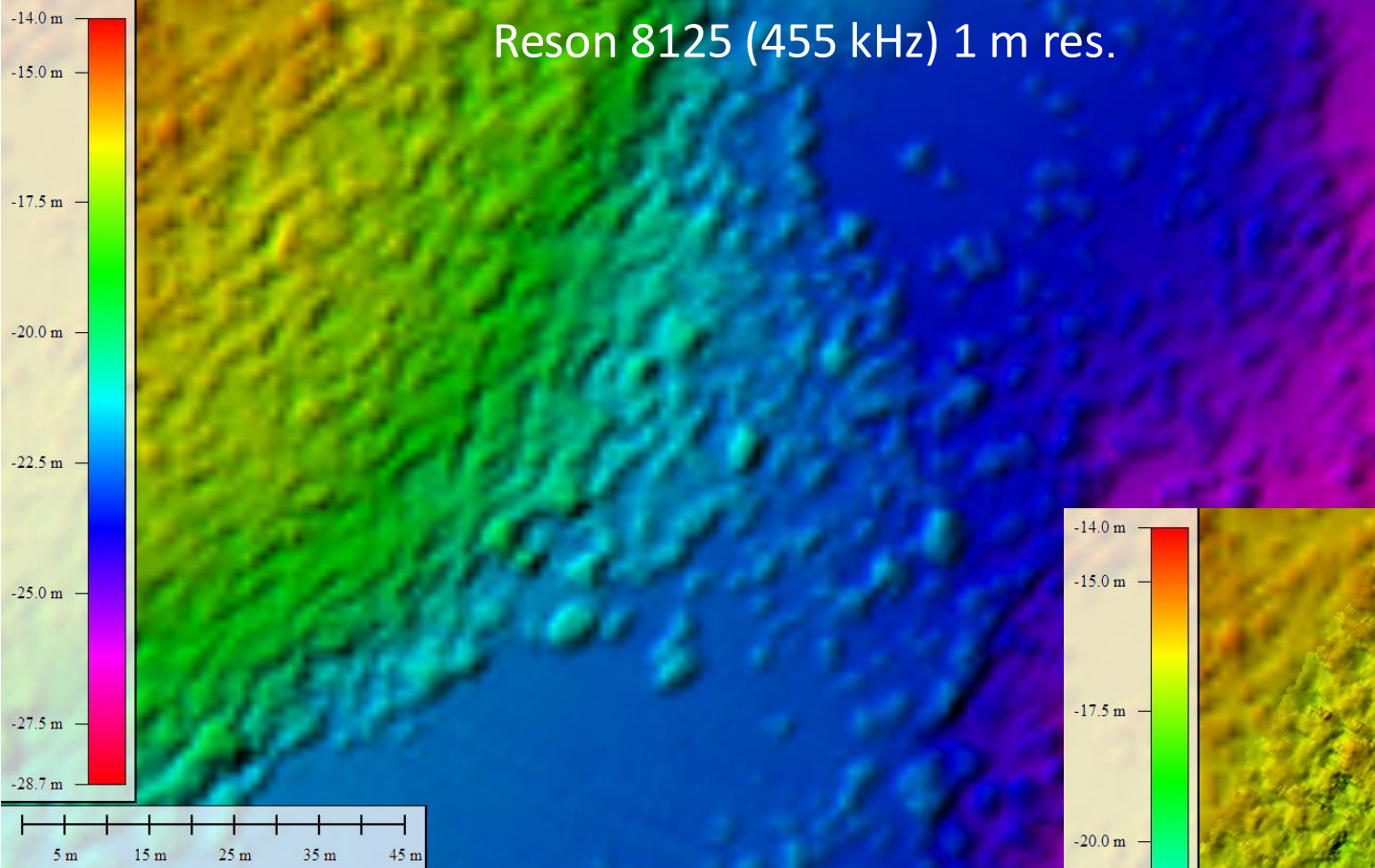
Panarea 2002



SEABAT RESON 8125
(455 kHz) - 2005

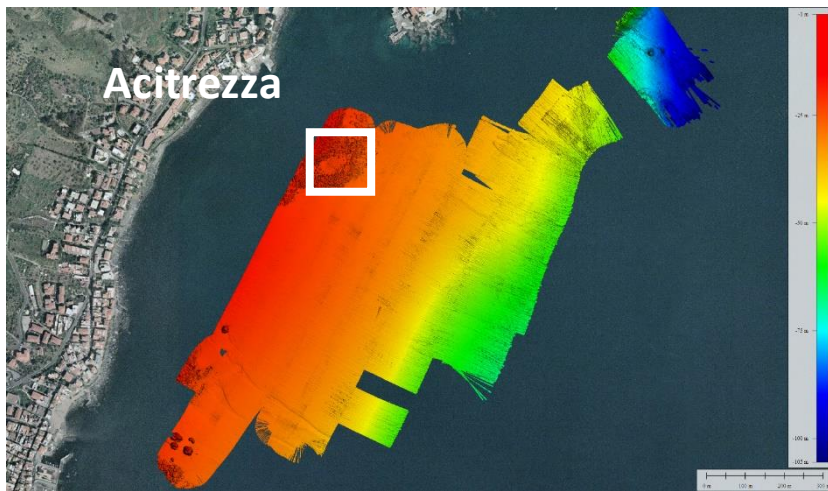
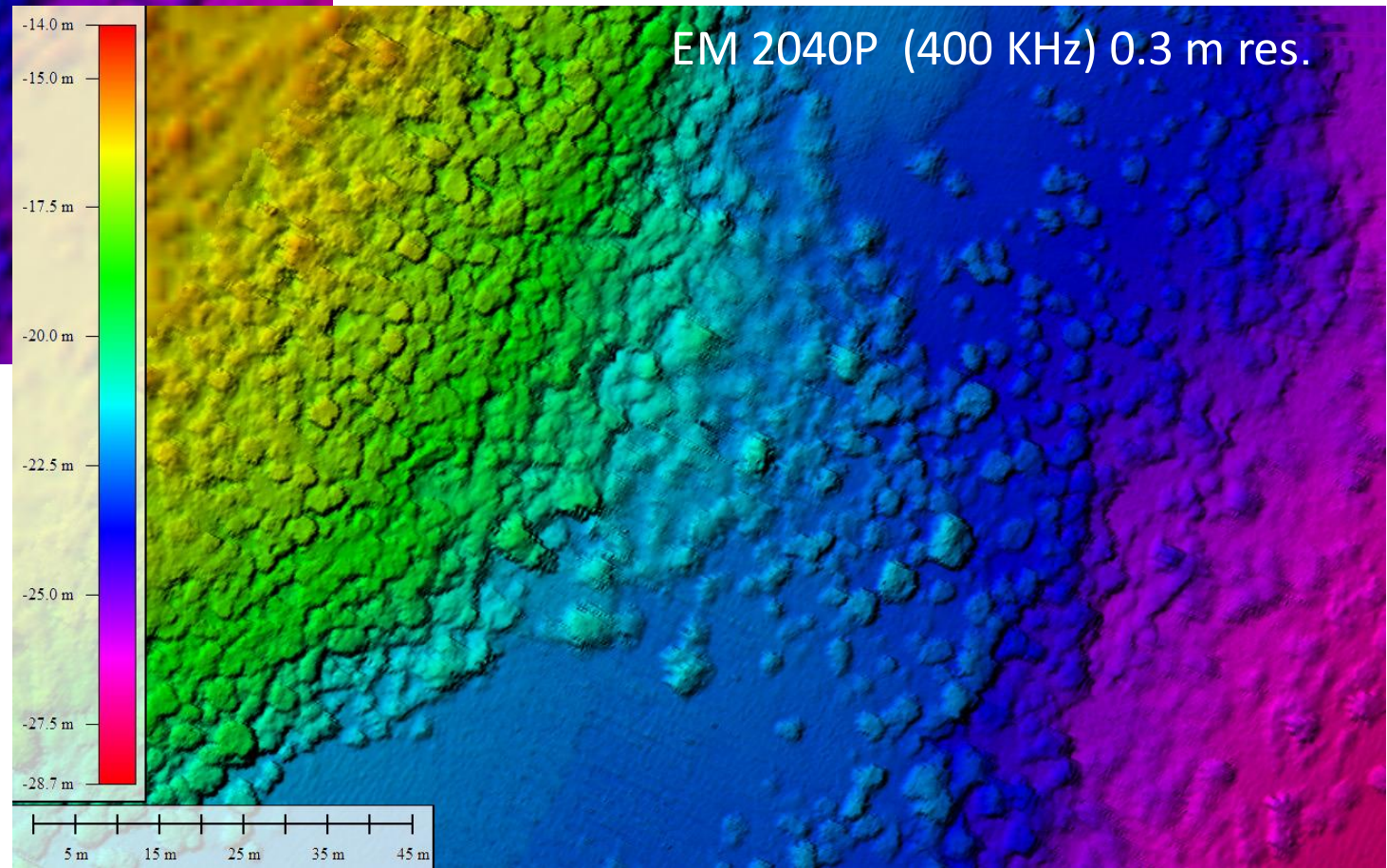
Kongsberg EM2040P
(400 kHz) - 2024



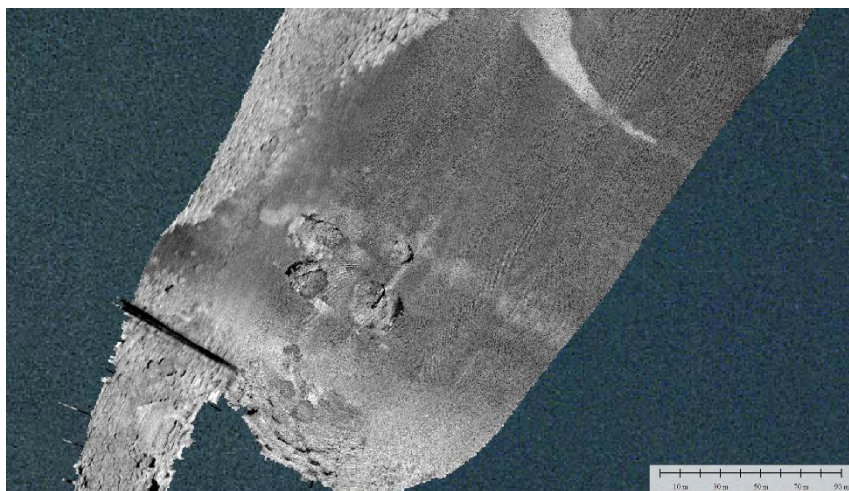
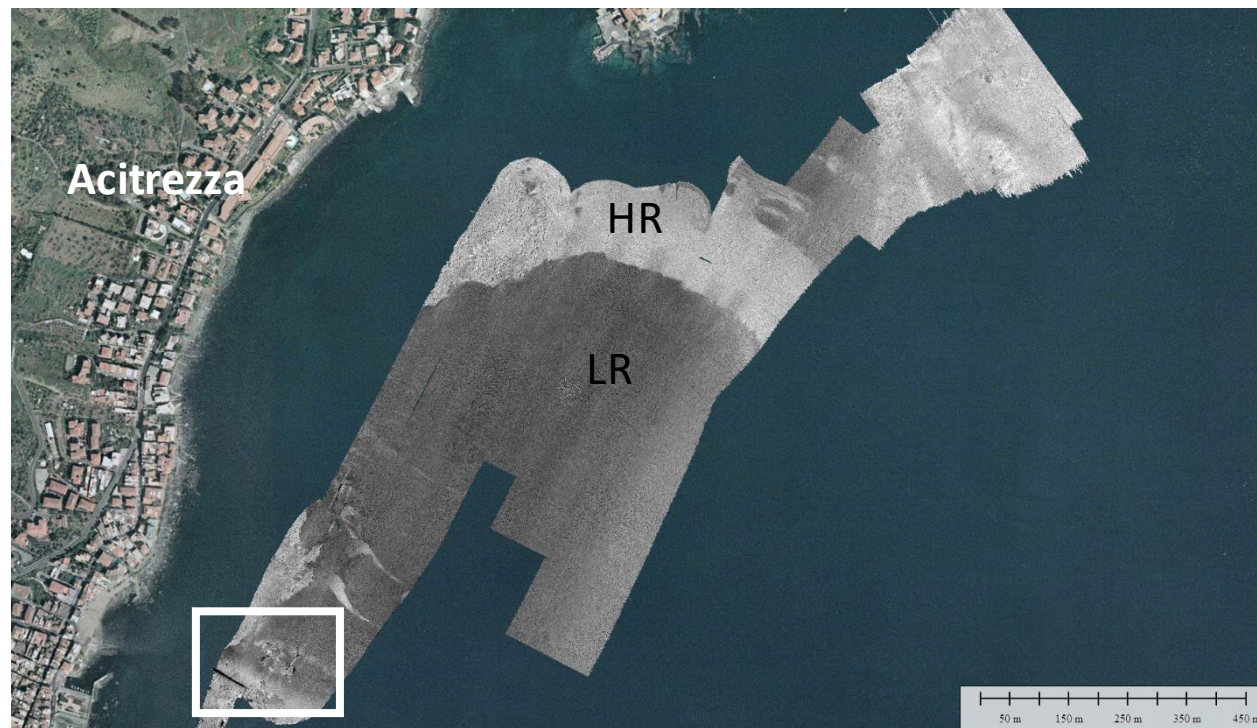


DATA RESOLUTION IMPROVEMENT

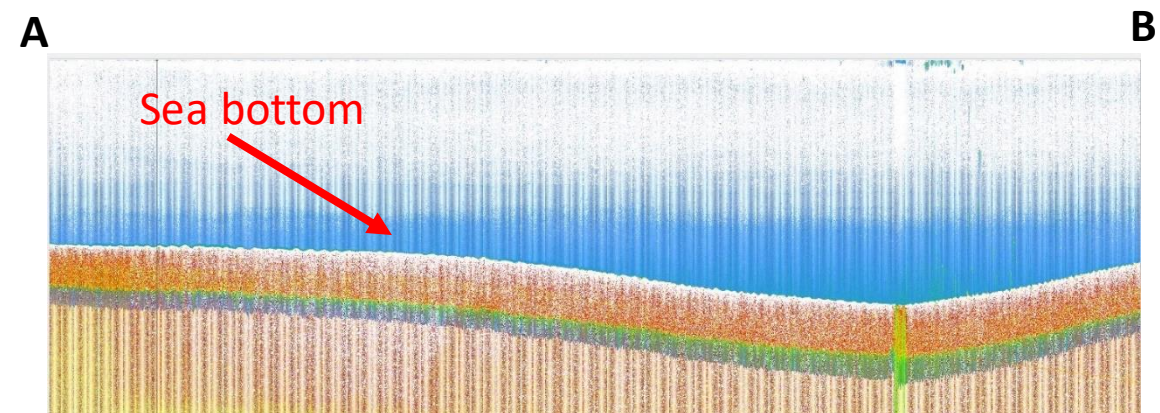
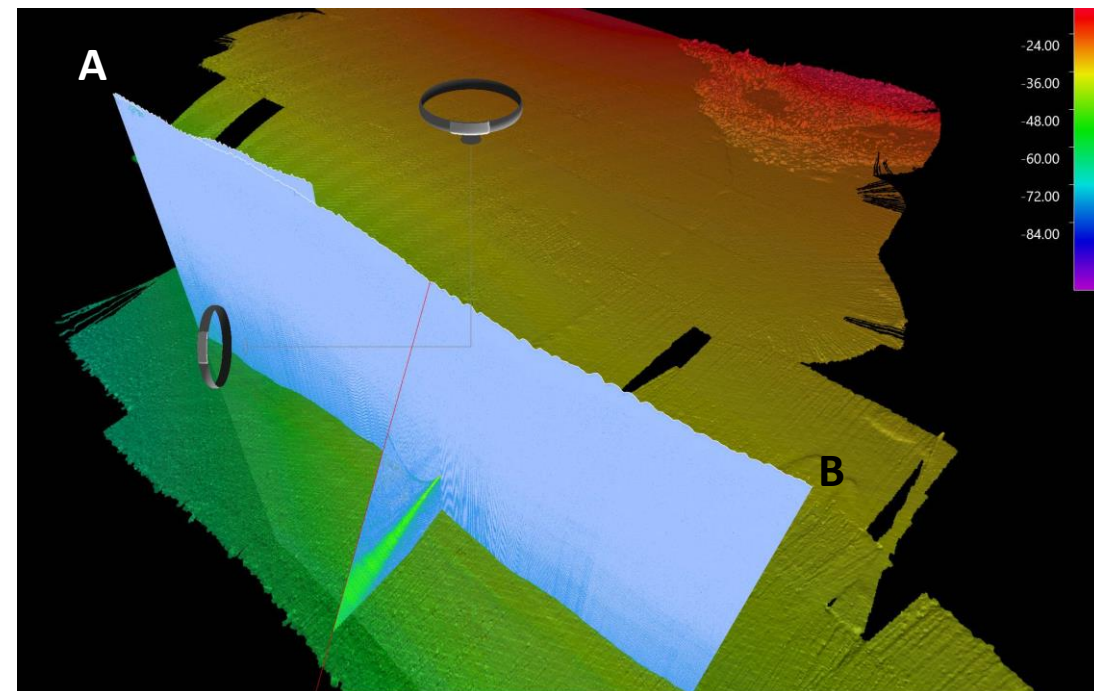
From 240 beams per swath
To 1024 beams per swath

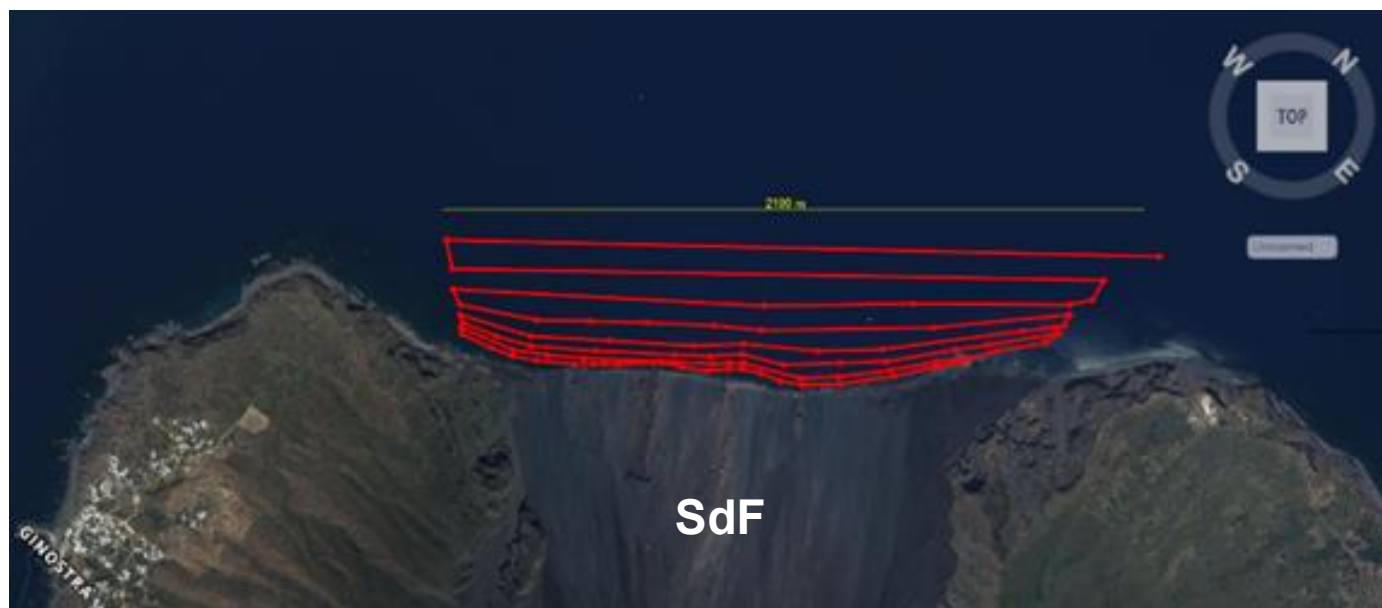


Backscatter - Reflectivity

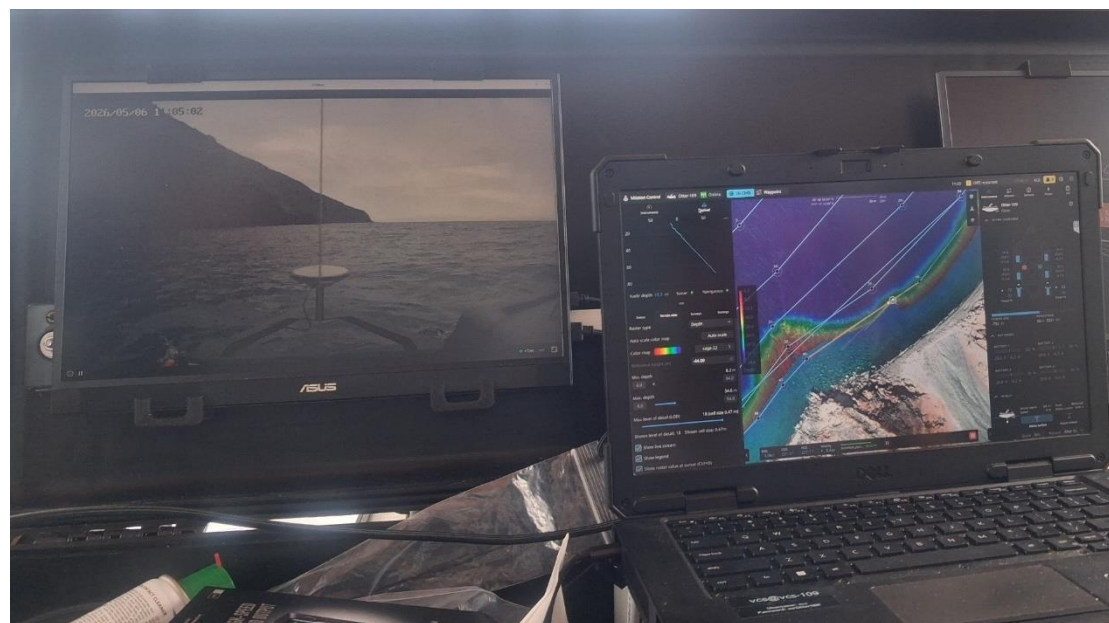


Water Column data





- In **May 5-6, 2026**, high-resolution bathymetric surveys of the submarine portion of the Sciara del Fuoco (Stromboli), from the nearshore sector to intermediate depths (2–400 m), were carried out, as part of the INGV Project '**Rete Multiparametrica**', for the first time using a marine surface drone (USV) equipped with an ultra-high-resolution multibeam echosounder (**Kongsberg EM2040P**) connected to a centimeter-precision inertial positioning system.



- The drone recorded bathymetric data along **8 lines** oriented parallel to the coastline, each about 2 km long, starting offshore and approaching the coast.

- The survey was carried out during an **effusive eruption of Stromboli**, which produced lava flows along the SdF that reached the sea. The effusive activity created a small lava delta that modified the coastline, forcing the operators to modify the planned routes closest to the shore in order to bypass the obstacle.



- Some **Calibration lines** were acquired to correct the transducer of the MultiBeam, ensuring data accuracy at the centimetric level.
- Several sound velocity measurements were carried out down to a depth of 90 m (using an **SVP** operated by the drone's winch).
- **Tidal data** were acquired using a digital tide gauge (Valeport TideMaster), specifically installed on the Ficogrande pier in Stromboli, which was necessary for real-time sea-level correction.

To carry out the survey, a support vessel (**the catamaran “Divina Kaskazi”**), equipped with a crane for launching and recovering the drone, was used. This made it possible to keep the drone constantly within visual range and ready for intervention in the event of malfunction, while always maintaining a safe distance from the area of greatest hazard.

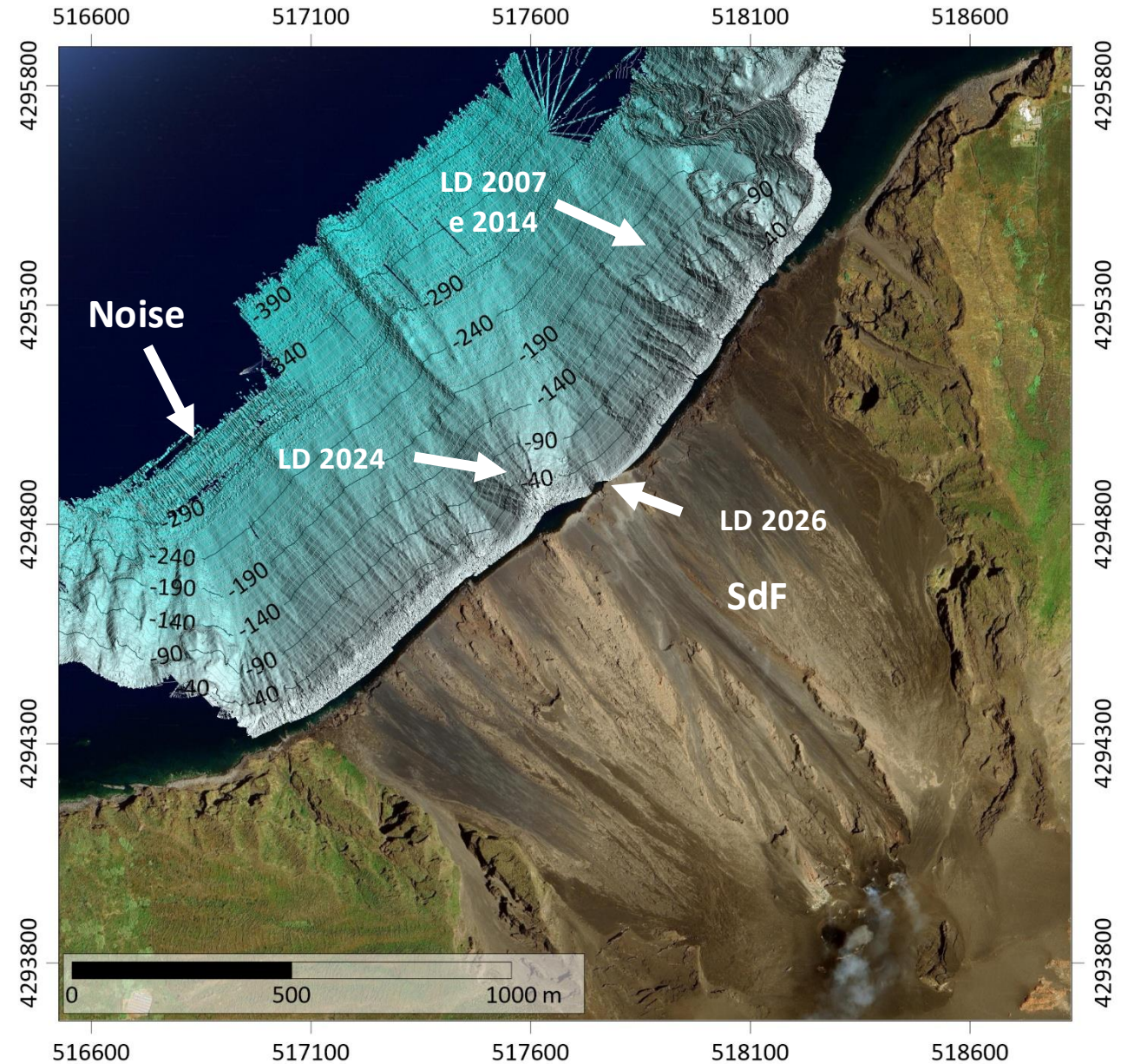


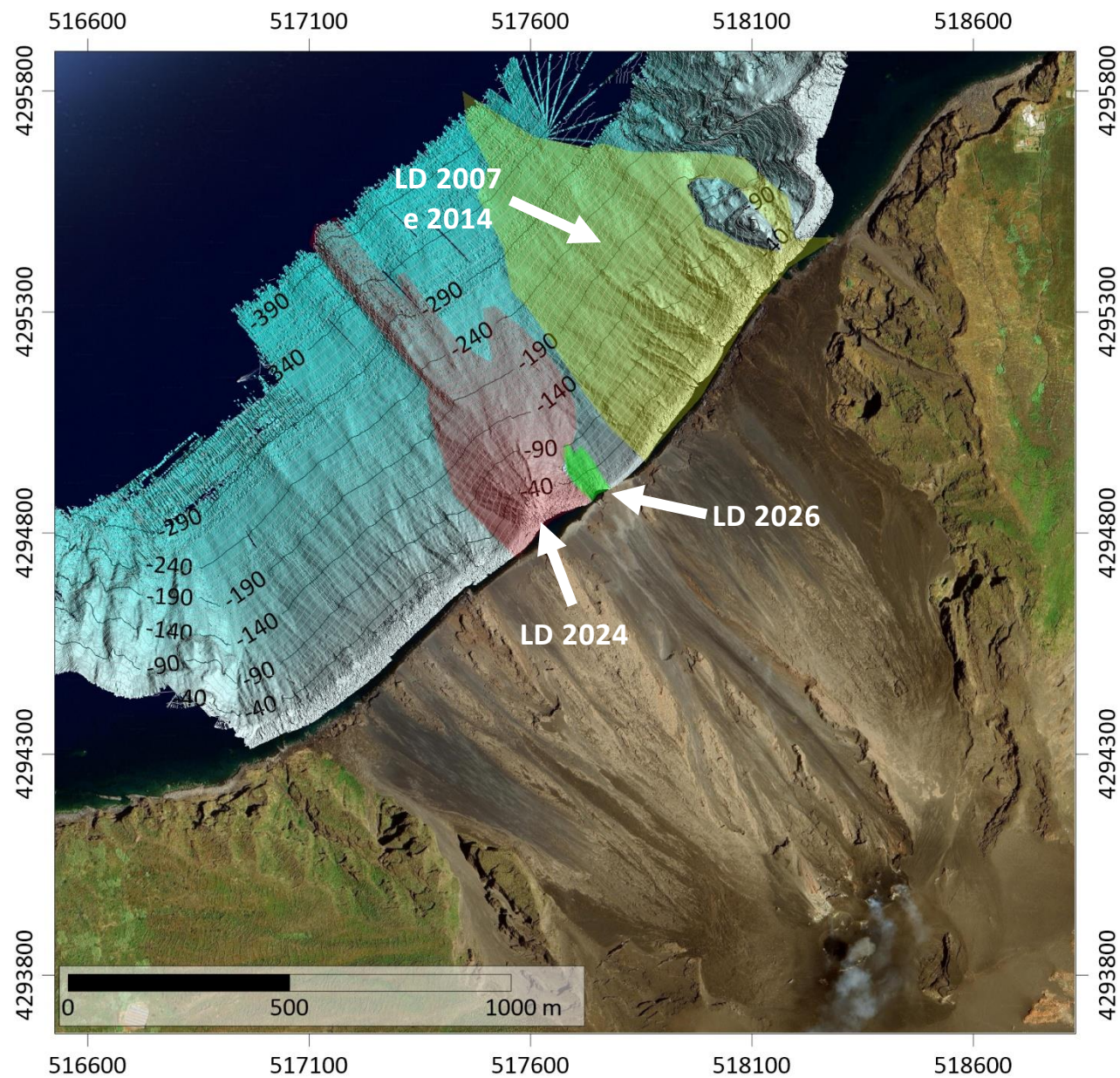
The catamaran “Divina Kaskazi”

The drone’s positioning was performed in **RTK (Real Time Kinematic) mode**, through the use of differential systems providing navigation signal corrections calculated from fixed ground-based GNSS stations with accuracies of a few cm, employing two different approaches: i) 4G internet connection (using the NTRIP protocol), which relied on the reference station sited in the center of Stromboli and belonging to the INGV sicili@net permanent station network; ii) UHF radio bands using a transmitting radio specifically installed at Punta Labronzo (with a good view over the SdF sea area) and a receiving radio installed on the drone. The latter approach was adopted because the nearshore sector of SdF has insufficient 4G coverage

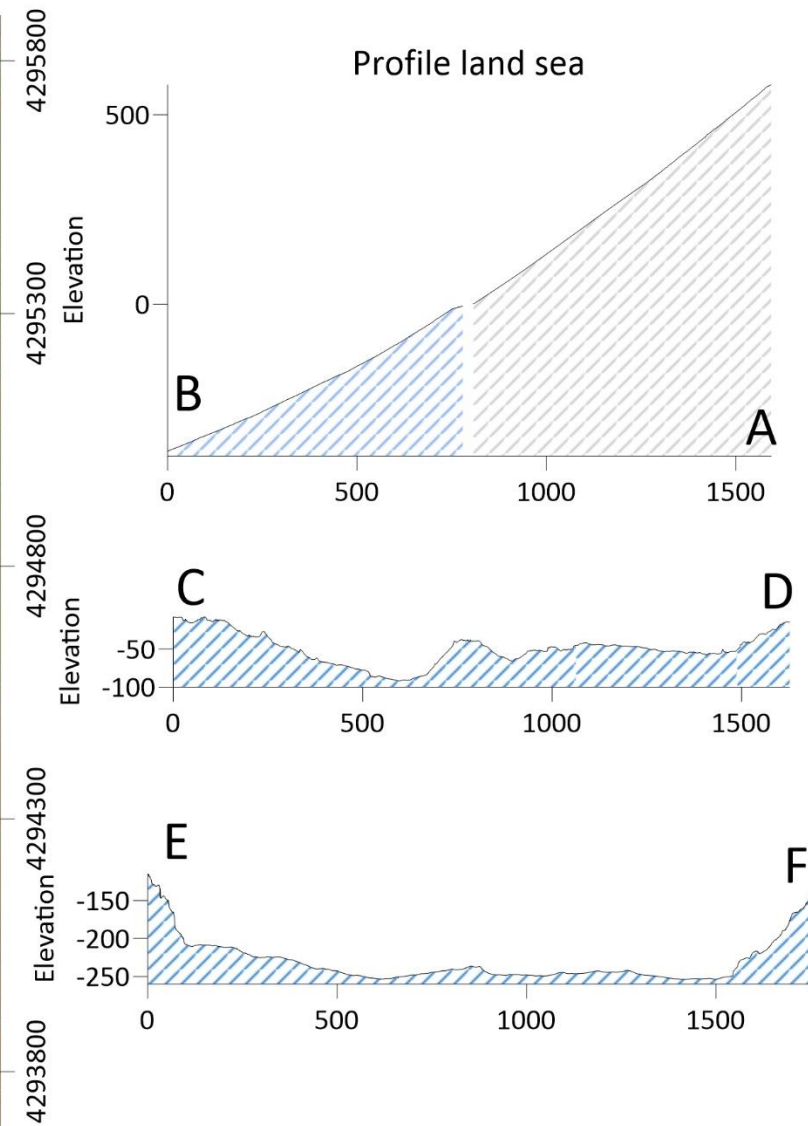
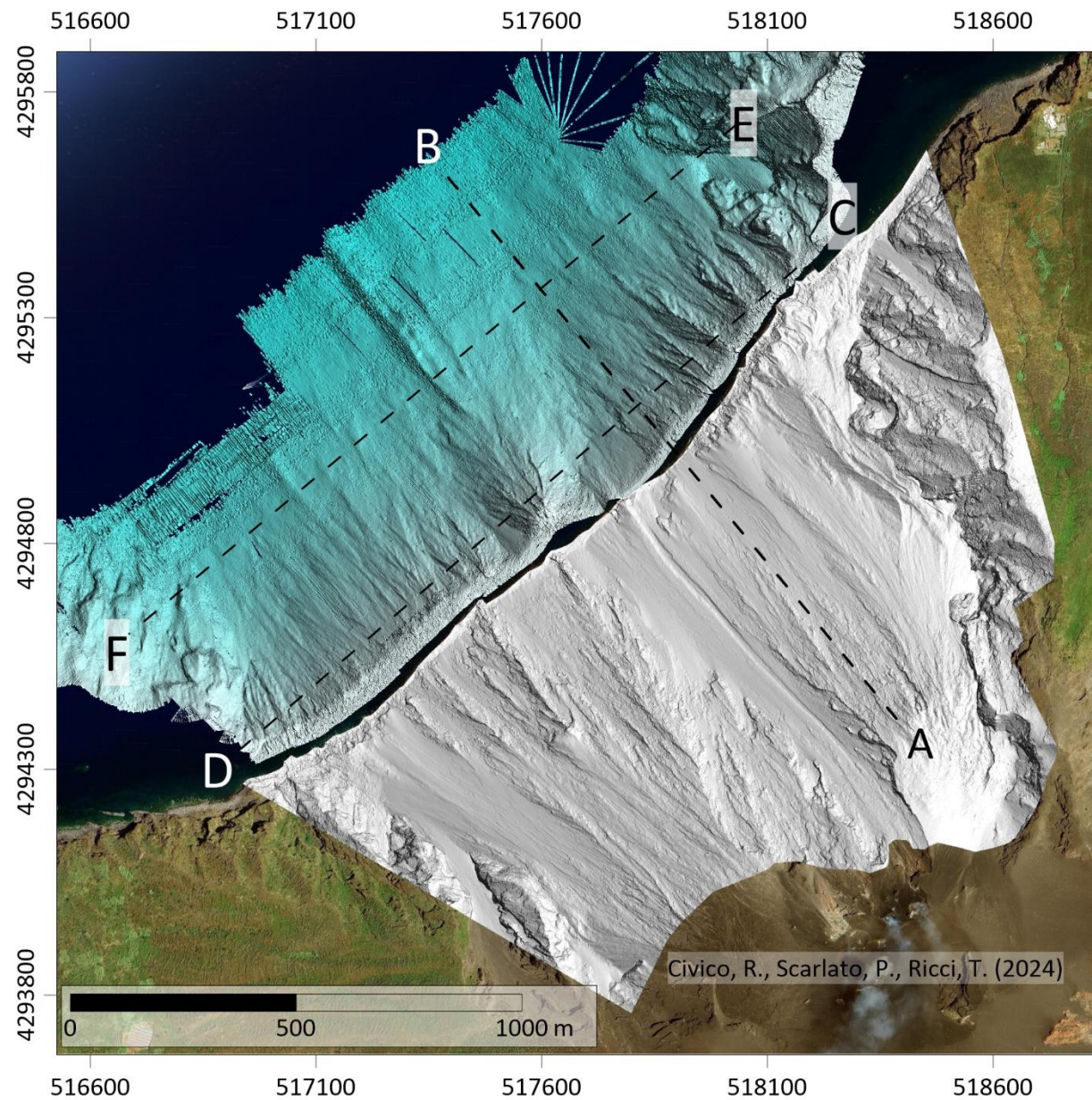
Preliminary results

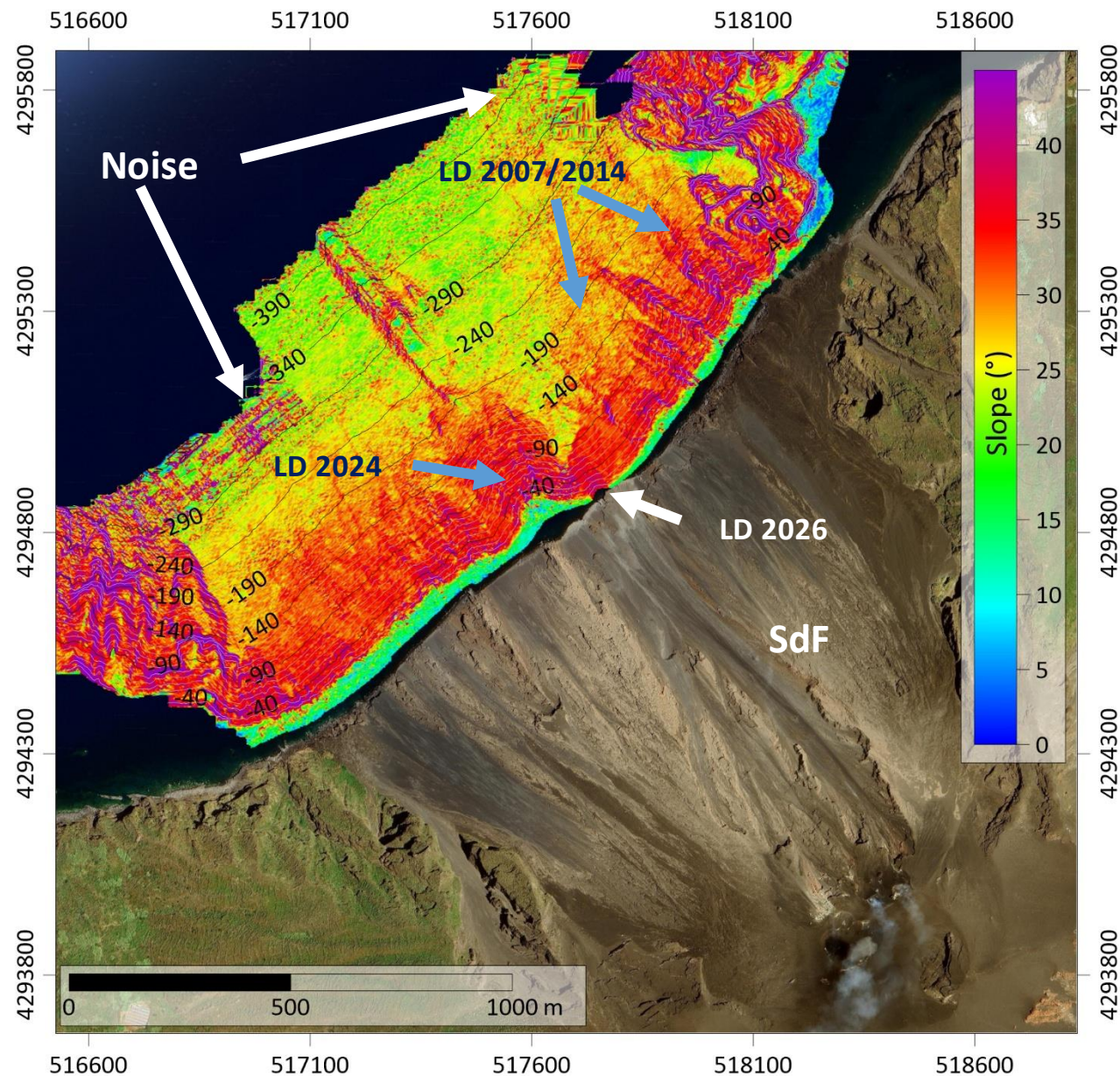
- CARIS HIPS&SIPS software was used for data processing (calibration and navigation computation, sound velocity and tidal variation corrections, noise filtering, and removal of spikes and noise), producing an HR **Marine Digital Terrain Model (MDTM)** of the seabed off SdF, with a grid cell-size of 20 cm down to a depth of 50 m and 50 cm down to about 400 m depth.
- The first results highlight the depositional/erosive structures formed by the impressive 2007 lava deltas, LD, (with superimposed smaller lava flows from 2014), the lava delta formed in 2024 and, between the two deltas, the small lava delta developed during May 2026.





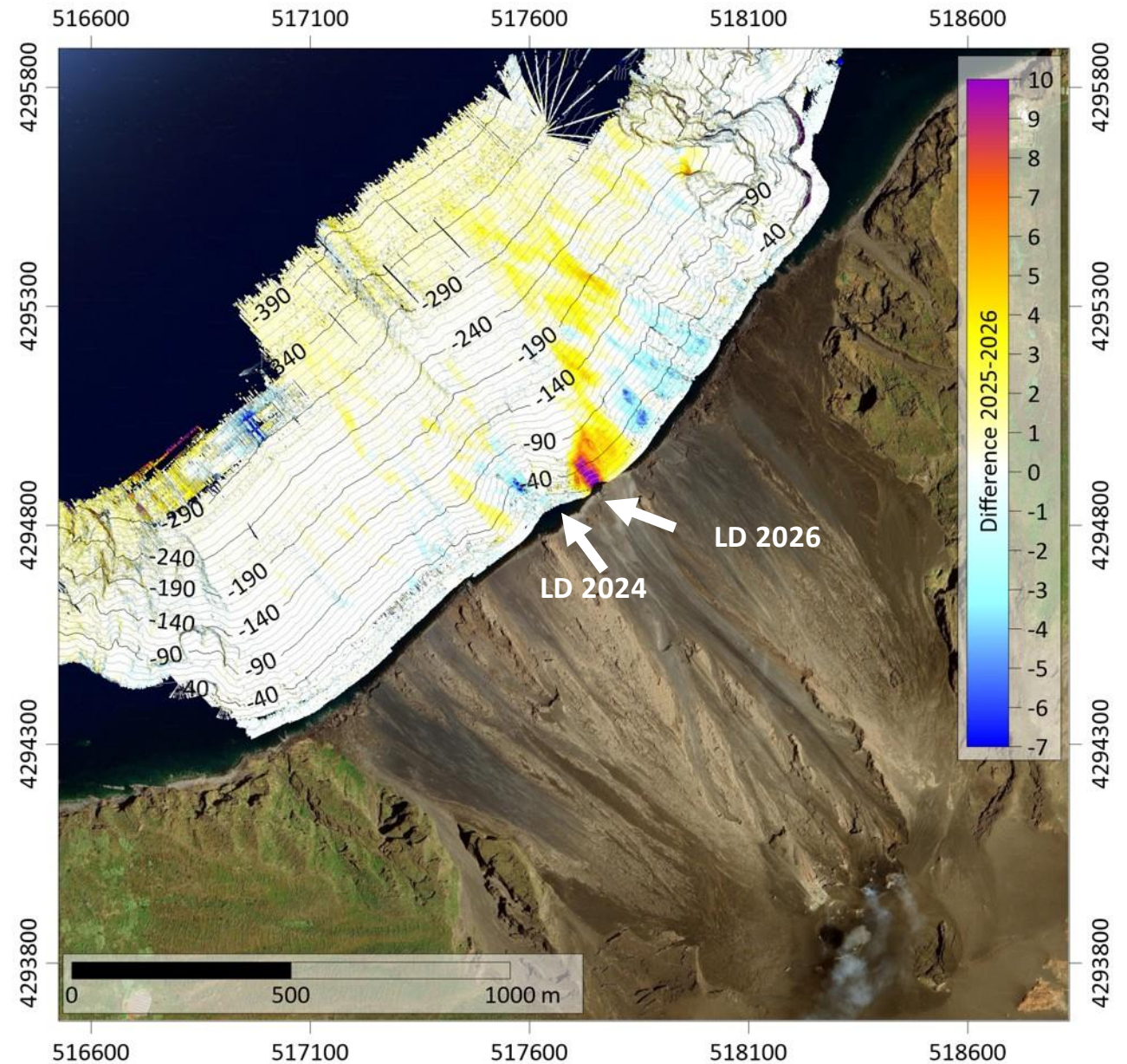
Marine Digital Terrain Model (MDTM)
of the seabed off Sciara del Fuoco
(Stromboli).





A **slope-gradient map** was also produced, showing the extremely steep slopes (up to 40°) corresponding to the 2007 and 2024 lava deltas and a nearly flat belt close to the coastline, representing the abrasion surface generated by wave action.

A **difference map** computed by comparing May 2026 and January 2025 bathymetries was also achieved highlighting the presence of the new lava delta (May 2026) and the intense erosion of the 2024 lava delta as well as the deposition of its remobilized portion.



A large, dark, and rugged volcano dominates the left side of the frame. Its slopes are steep and covered in dark, rocky material, with some patches of green vegetation visible on the left. A plume of white smoke or steam rises from the summit, drifting towards the right. The volcano is situated next to a body of water, which occupies the bottom third of the image. The sky is filled with soft, white clouds.

Thank you for
your attention

We would like to thank Simone Di Giacomo for the fundamental and continuous support during the purchase of the drone+MBES and the assistance during the tests and the crew of the catamaran “Divina Kaskazi” for its work during the surveys.