

The new Italian LiDAR Digital Surface and Terrain Models and Airborne gravimetry Database

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S8: International projects
XI Hotine-Marussi Symposium
Genoa, 10 September 2026

Outline

1. State-of-the-art
2. Project goal and objectives
3. Reference frame
4. Quality requirements, data and products: LiDAR and airborne gravimetry surveys
5. Conclusions and future prospects

State-of-the-art - Topography (DSM and DTM)

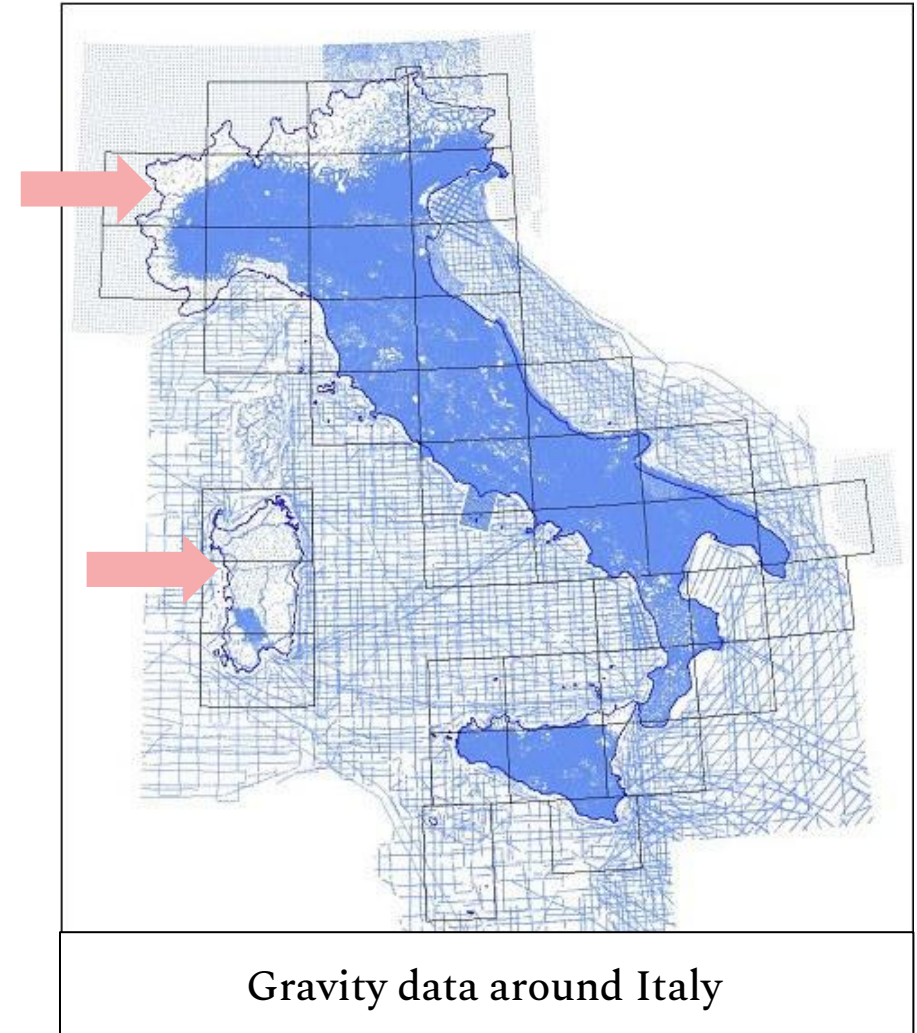
High-resolution digital terrain (DTM) and surface models (DSM)
(**grid spacing ≤ 1 m** – *Orthoimage and Altimetric Model Guidelines 1:10000*, CISIS, 2009):

- produced at **region, province, and municipality level**
- **heterogeneous** in terms of **epoch, characteristics, and accessibility**

State-of-the-art - Gravity field and geoid (Gravimetric database)

Gravimetric database:

- **incomplete** (missing data for Alpine areas, Sardinia, Apennines; lacking metadata on measurement accuracy and reference frames)
- **heterogeneous** (data collected over more than 30 years, starting from the 1950s)
- **not publicly accessible** (ISPRA)



Goal

- **Align national geoinformation with international standards** to meet the needs of:
 - central and local administrations
 - universities and research institutions
 - private sector
- acquiring **state-of-the-art data** using **LiDAR and airborne gravimetric sensors**
- **solving current heterogeneity** in quality and epoch
- guaranteeing **public accessibility**

Objectives

- **Acquisition and processing of LiDAR and airborne gravimetry data** over the entire national territory - 302,073 km²
- Delivery of **raw data** and derived **products**
- **DSM and DTM** with quality suitable **for hydraulic modelling**
- **Digital models of:**
 - **key gravity field quantities**
 - **new gravimetric geoid model**, to support the realization of the **new national geoid** (gravimetric geoid + GNSS leveling)

Reference Frame, Coordinate Systems, Metadata

- **National reference frame: ETRF2000 (epoch 2008.0) – RDN2008 (EPSG)**
(Decree 10 Nov 2011 – *Adoption of the national geodetic reference frame*)
- **Coordinate systems:**
 - **cartesian geocentric** (X, Y, Z) – EPSG 6704
 - **ellipsoidal** (φ , λ , h) – EPSG 6705
 - **geographic** (φ , λ) – EPSG 6706
 - **UTM cartographic** (E, N – Italy zone) – EPSG 7794
 - **orthometric heights** with new geoid model
- **Metadata** compliant with the **National Repository of Territorial Data** (RNDT) – v. 2.0.1

LiDAR Surveys

Data/Product features and quality requirements

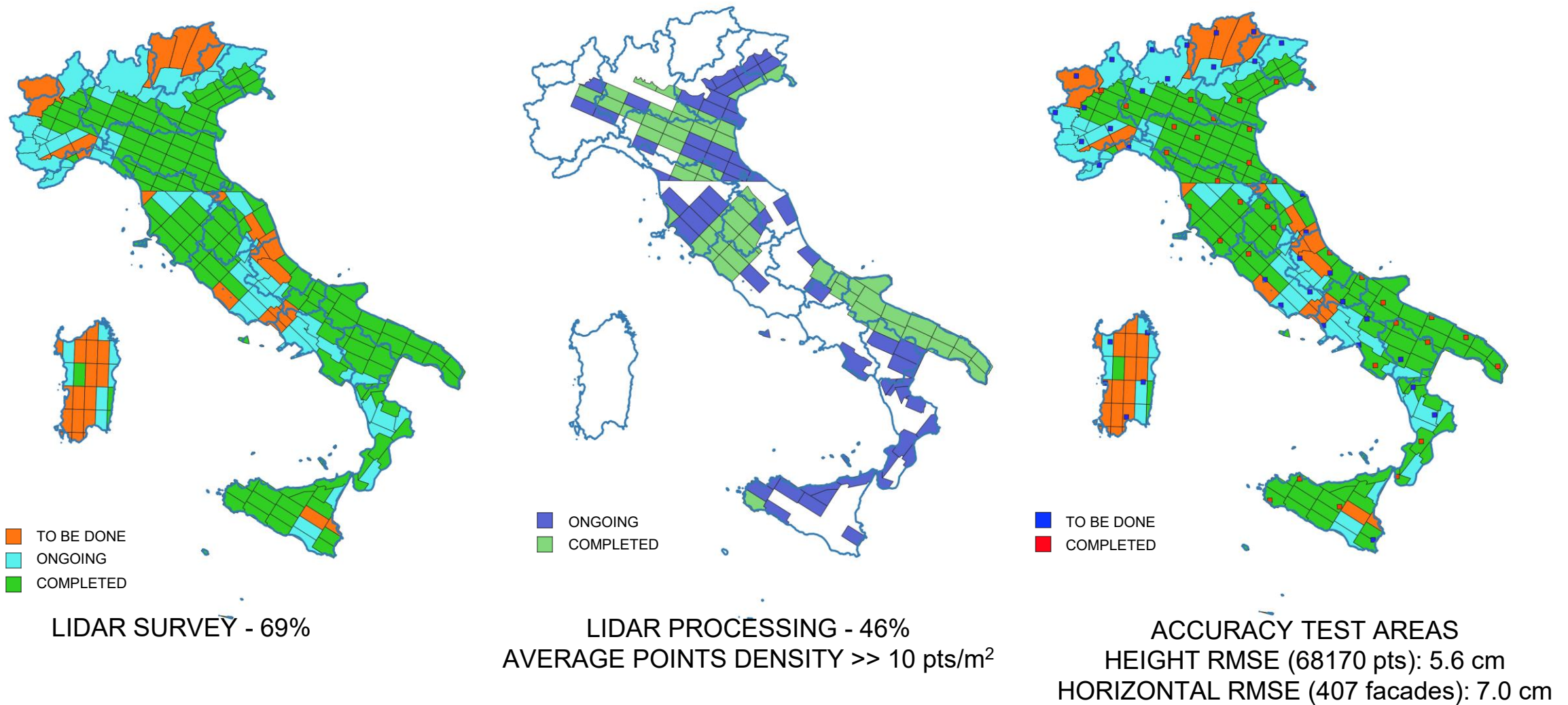
- **Surveys main features:**
 - LiDAR sensor: ≥ 4 echoes per emitted pulse
 - Homogeneous blocks according to morphology
 - Cross-track - along-track overlaps: $\geq 20\%$ and $\geq 50\%$
 - Calibration and verification for each mission on test areas near airports
 - **Extensive use of Single Photon LiDAR** ($\sim 60000 \text{ Km}^2$, first time in Italy, on the Alps)
- **Accuracy/density requirements:**
 - **70 test areas** over Italy (ground truth: kinematic GNSS + terrestrial laser scanner)
 - **vertical RMSE $\leq 0.06 \text{ m}$** (flat, obstacle-free terrain)
 - **horizontal RMSE $\leq 0.10 \text{ m}$**
 - **point density $D_m \geq 10 \text{ points/m}^2$**

LiDAR - Data and Products

Tiles of constant size $1 \text{ km} \times 1 \text{ km} / 0.01^\circ \times 0.01^\circ$:

- Raw LiDAR data (point cloud in LAZ, ellipsoidal coordinates), outlier removed
- **Classified point cloud** (“Ground” and “Overground”) in LAZ, ellipsoidal coordinates
- Intensity in GeoTIFF (8-bit grayscale)
- **DSM (first pulse, last pulse), DTM** from filtered last-pulse DSM
- **Gridded models:** spacing $0.25 \text{ m} \times 0.25 \text{ m} / 0.0000025^\circ \times 0.0000025^\circ$

LiDAR - Results: work progress, density, accuracy



Airborne gravimetry surveys

Data/Product features and quality requirements

- **Surveys main features:**

- Gravity measurement accuracy: $\text{RMSE} \leq 1.5 \text{ mGal}$
(instrument: strapdown airborne gravimeter IMAR-iCORUS)
- Homogeneous blocks (constant flight height) flown in single sessions
- Flight line lengths: 50–100 km, maximum airplane speed 220 km/h
- Maximum relative altitude: $D_{\text{hmax}} \leq 2000 \text{ m}$ (exceptions: Alps, Apennines, Etna)
- Spacing between parallel flight/cross-check lines: $\leq 2.2 \text{ km}$, $\leq 31.1 \text{ km}$
- Overlap between adjacent blocks: $\geq 10 \text{ km}$



- **Accuracy/completeness requirements:**

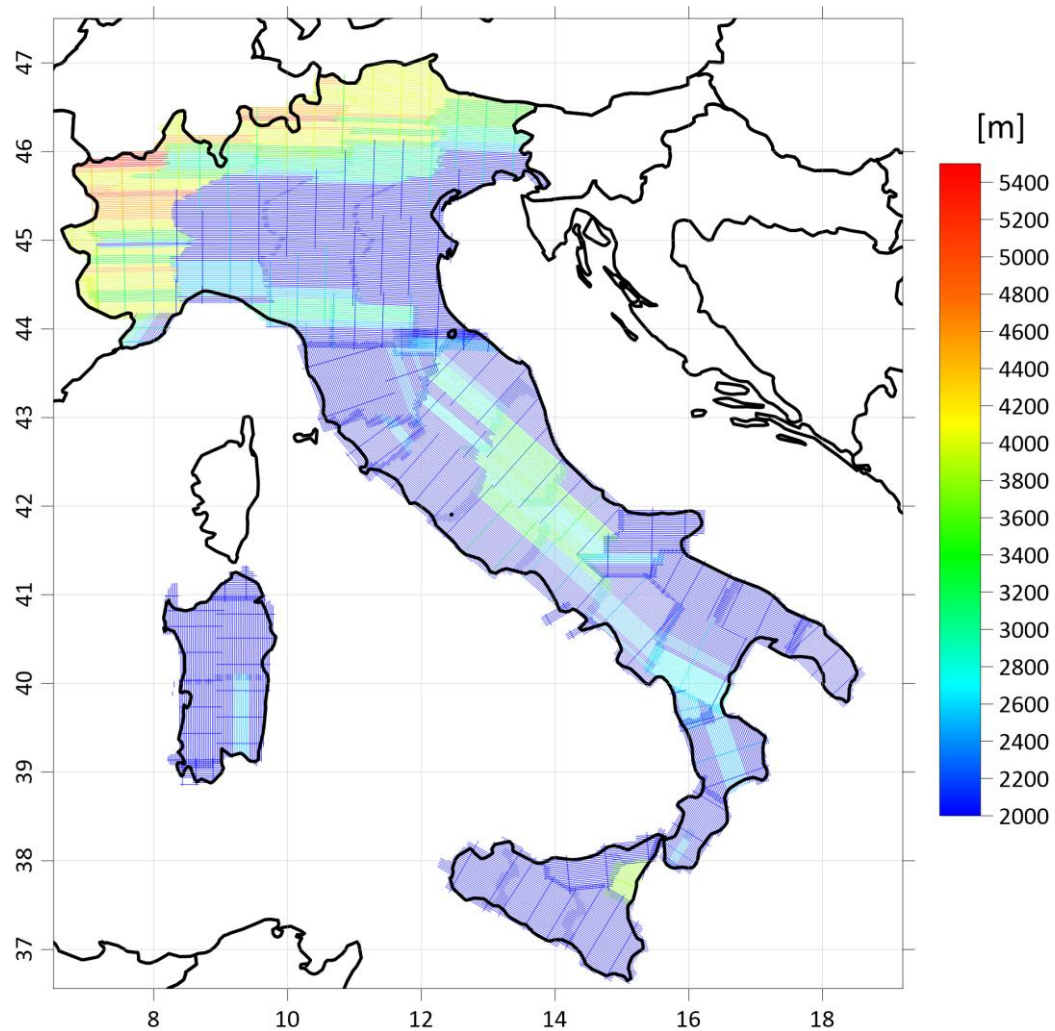
- **Cross-over RMSE $\leq 0.8 \text{ mGal}$**
- **Gravity data density $D_{\text{mG}} \geq 1 \text{ point/5 km}^2$**

Airborne gravimetry - Data and Products

Nationwide unique tile:

- Gravity disturbance filtered along flight tracks: along-track spacing 2.5 km
- **Gridded models from filtered data:** spacing $2.5 \text{ km} \times 2.5 \text{ km} / 0.025^\circ \times 0.025^\circ$ (Copernicus DEM EEA-10 chosen as reference DTM)
 - **topographic corrections** at 4000 m (ell. height) and on Copernicus DEM EEA-10
 - **gravity disturbance** (with predicted pointwise error) at 4000 m (ell. height) and on DTM
 - **Bouguer anomaly** at 4000 m (ell. height) and on DTM
 - **gravimetric geoid** undulations with predicted pointwise error

Airborne gravimetry - Flights and work progress



Airborne gravimetry - Results: preliminary statistics on processed blocks

Block	min(obs)	MAX(obs)	E(obs)	st.dev.(obs)	min(rid)	MAX(rid)	E(rid)	st.dev.(rid)	GGM/ITALGEO05
G6	27.85	87.15	52.83	10.81	-10.94	14.23	-1.89	3.70	XGM2019e (2160)
GN22	-135.84	5.65	-100.13	32.27	-17.23	10.87	-2.08	4.00	XGM2019e (2160)
GN26	-90.99	89.48	22.83	31.35	-11.07	11.05	0.00	3.58	XGM2019e (2160)
GN25	-120.00	91.74	-2.54	55.48	-14.81	21.87	0.08	5.35	XGM2019e (2160)
GN25	-120.00	91.74	-2.54	55.48	-19.38	14.62	0.05	4.77	XGM2019e (5540)
GN25	-120.00	91.74	-2.54	55.48	-14.86	17.93	0.55	4.09	ITALGEO2005

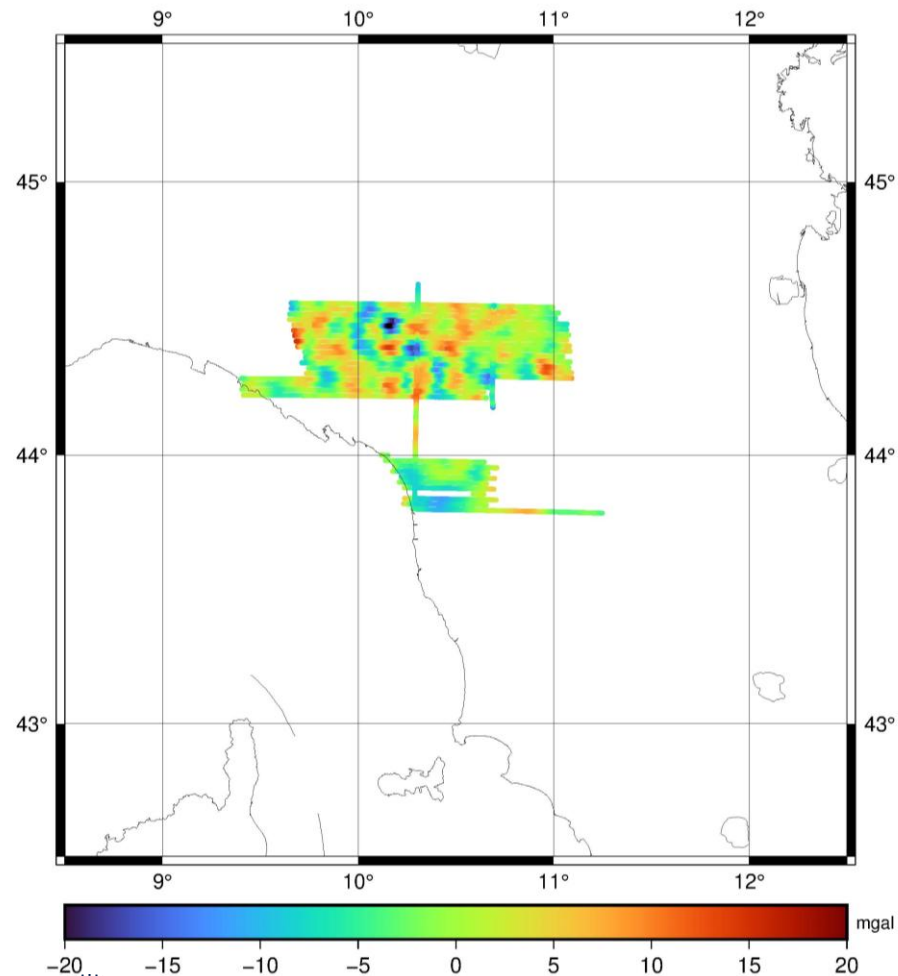
(values in mGal)

$$\delta g_{\text{rid}} = \delta g_{\text{obs}} - \delta g_{\text{GGM}}$$

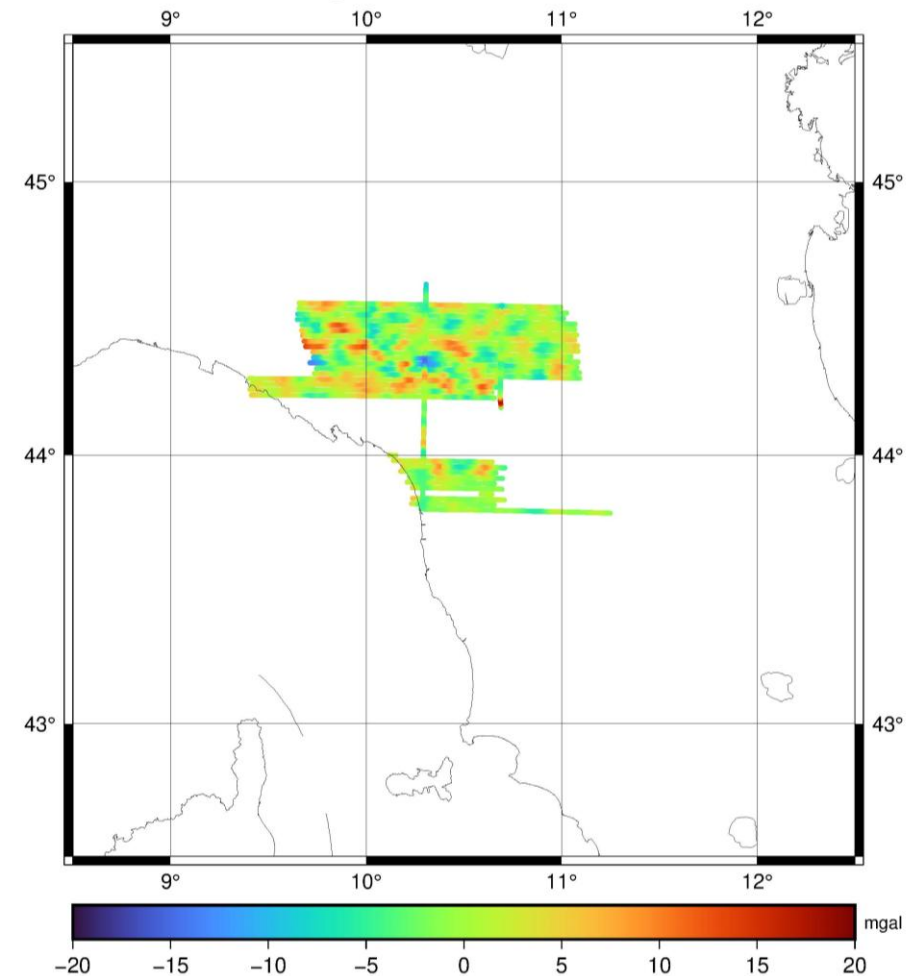
$$\delta g_{\text{rid}} = \delta g_{\text{obs}} - (\delta g_{\text{GGM}} + \delta g_{\text{r}} + \delta g_{\text{topo}})_{\text{ITALGEO2005}}$$

Airborne gravimetry - Results: gravity residuals on block GN25

XGM2019e - Observed



Italgeo05 - Observed



The parallel aerogravimetry project MER: surveys along the Italian coasts



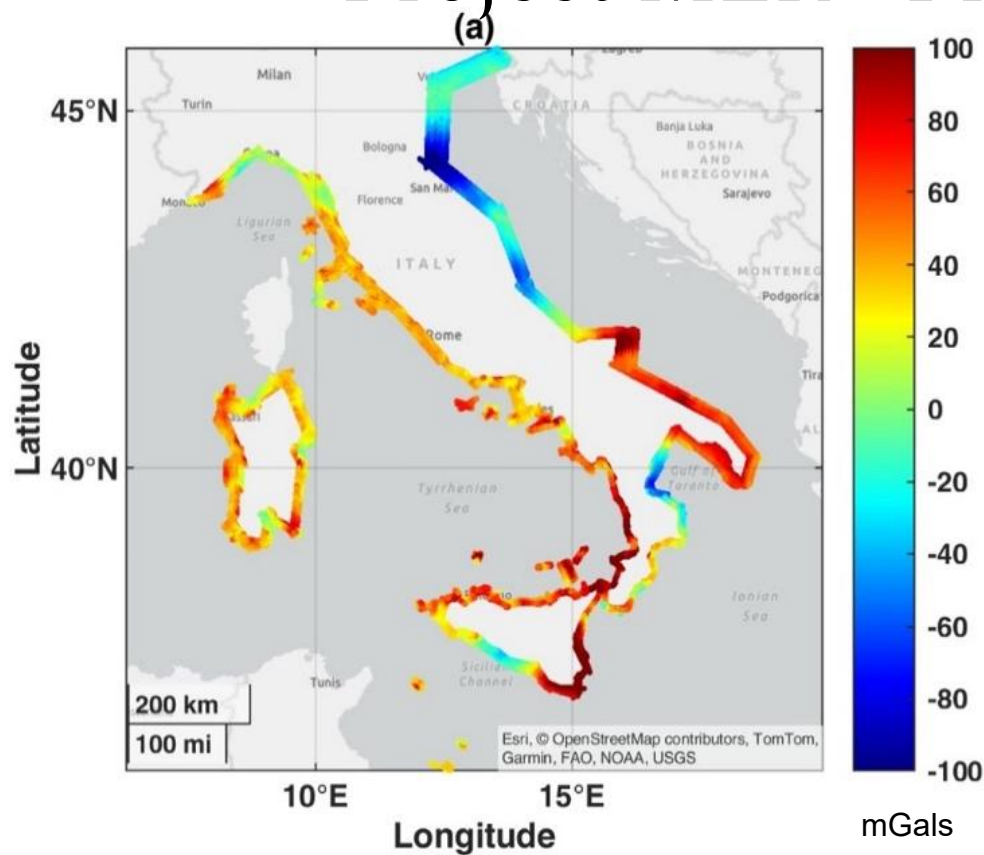
Aerogravimetry flights plan

Surveys main features:

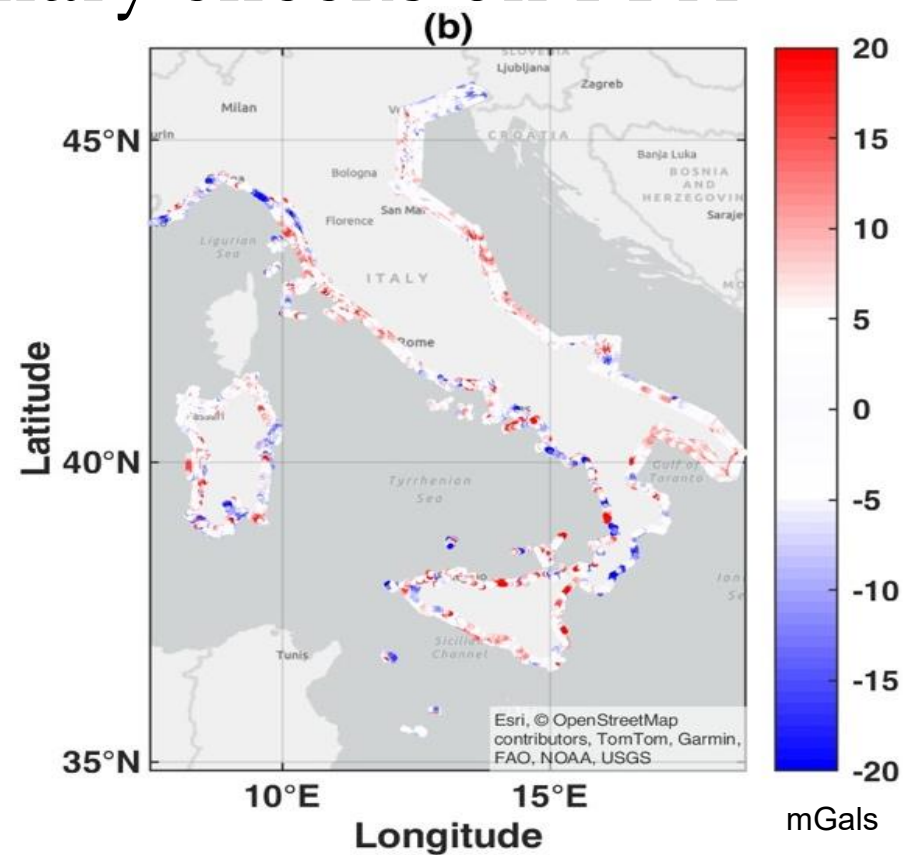
- surveys coupled with bathymetric LASER surveys and the in stand-alone mode
- spacing between parallel lines 300 m - 3 km
- spacing between cross-tracks 20 km
- flight altitude between 200 m and 3000 m
- maximum airplane speed 280 km/h
- strapdown airborne gravimeter IMAR-iCORUS



Project MER - Preliminary checks on FFA



FAA (aerogravimetry) along the Italian coastlines



Residuals between FAA(XGM2019_e; d/o 2190) and FAA (aerogravimetry)

n	M[Δ] (mGal)	σ [Δ] (mGal)
593460	0.42	8.10

$$\Delta = \text{FAA}(\text{XGM2019}) - \text{FAA}(\text{aerogravimetry})$$

Conclusions and perspectives

- **Public availability of data and products** enabling:
 - applications and generation of **value-added homogeneous products** across Italy
 - **education** and training activities on their use nationwide
 - state-of-the-art future **scientific research**
- **Significant advance to Italian geodetic databases**
(**expected precision of new geoid at 1 cm level**)
- **Long-term, virtuous investment** under the Italian PNRR (National Recovery and Resilience Plan, after pandemic)
- Project completion expected for winter 2026-2027

**Thank you very much
for your kind attention**