# Coastal dune modelling from airborne lidar, terrestrial lidar and Structure from Motion–Multi View Stereo

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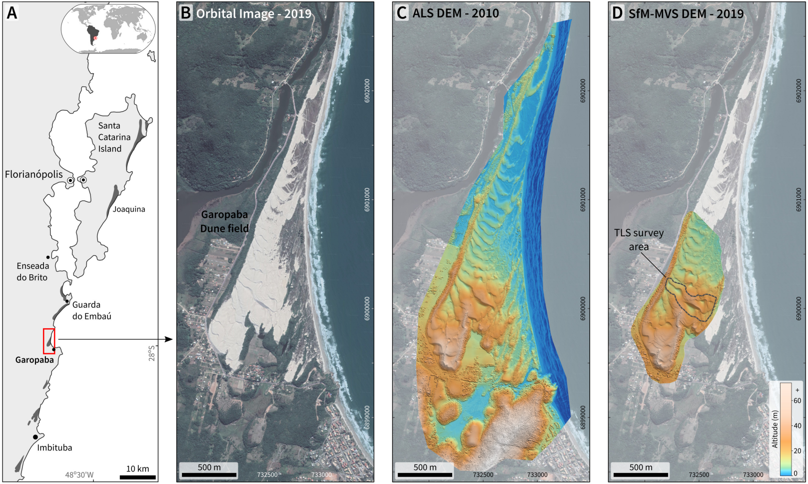
Geomorphometry2021 - Perugia, Italy

# Intro

- Sand dunes are commonly regarded as a challenge to traditional photogrammetry due their homogeneous texture and spectral response.
- In this work we present an evaluation of Structure from Motion–Multi View Stereo (SfM-MVS) to obtain high-resolution elevation data of coastal sand dunes based on images acquired by Remotely Piloted Aircraft (RPA)
- Altimetric accuracy of the SfM-MVS DEM was validated by comparison with Terrestrial lidar (TLS) data collected during the same fieldwork campaign of the RPA flights
- The SfM-MVS DEM was then compared to an Airborne lidar (ALS) DEM from October 2010

# Location

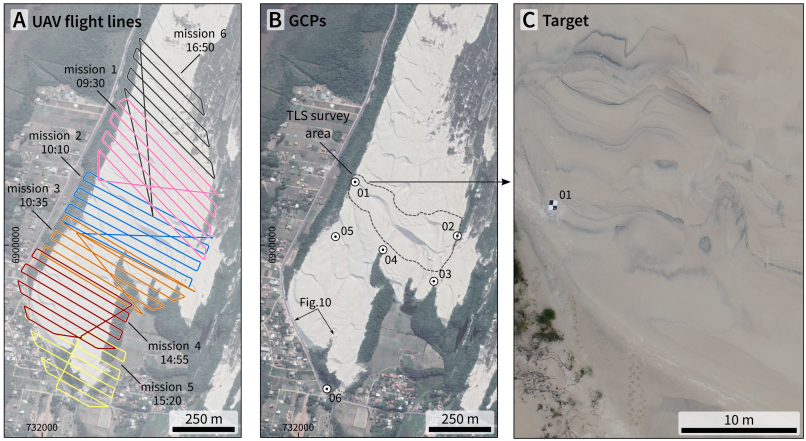


A
Santa
Catarina
Island
Florianópolis
Joaquina
Enseada
do Brito
Guarda
do Embaú
Garopaba
Imbituba
28°S
48°30'W
10 km
B Orbital Image - 2019
Garopaba
Dune field
500 m
732500
733000
6902000
6901000
6900000
6899000
C ALS DEM - 2010
500 m
732500
733000
6902000
6901000
6900000
6899000
D SfM-MVS DEM - 2019
TLS survey
area
500 m
732500
733000
6902000
6901000
6900000
Altitude (m)
+
60
40
20
0

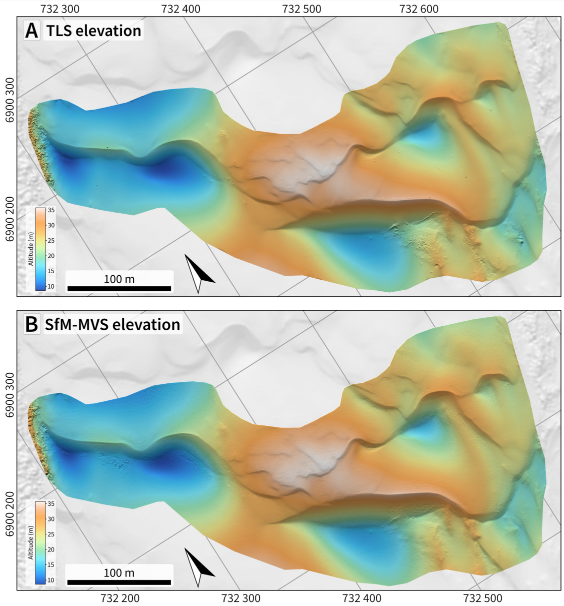
# Methods

- Airborne lidar (ALS) - Oct/2010 - 2pts/$m^2$
- Fieldwork - Feb/2019
- Terrestrial lidar (TLS) - FARO Focus s120 (110 scans, 3 days)
- SfM-MVS - DJI Phantom 4 (20 MP) - 6 flights, 810 images (3 hours)
- Software: FARO Scene, Agisoft Metashape, LAStools, GRASS-GIS and WhiteboxTools via Jupyter notebooks

# RPA flights, TLS area and GCPs

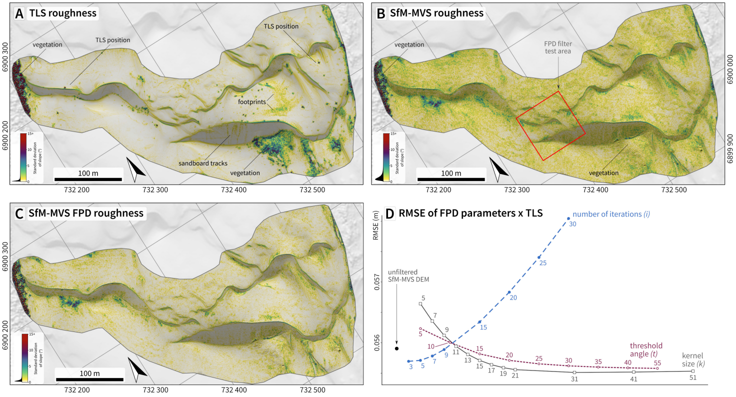


# Results - TLS x SfM-MVS



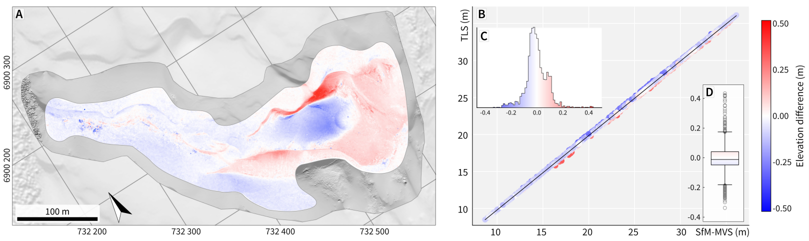
# Surface roughness

- Surface roughness - standard deviation of slope (Grohmann et al., 2011)
- Feature Preserving DEM Smoothing (FPD) algorithm (Lindsay et al., 2019)
- Evaluated change of RMSE from TLS DEM with FPD parameters
- Applied k=17x17, t=20°, i=5



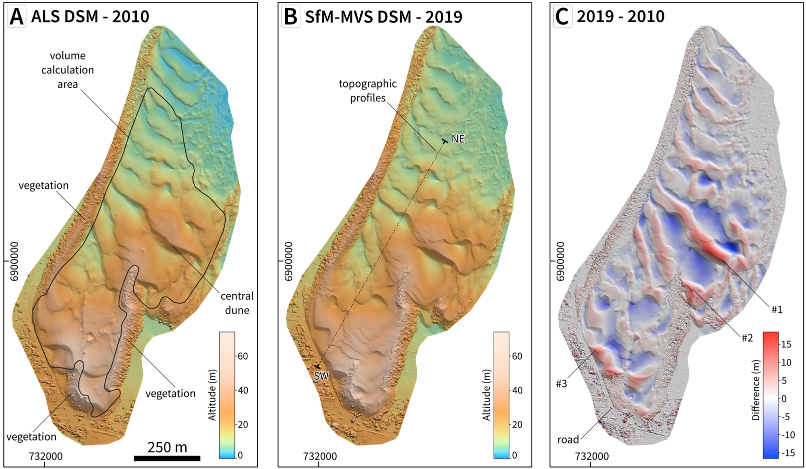
# TLS x SfM-MVS differences

- RMSE 0.08m, MAE 0.06m - original and FPD-filtered DEM (in masked area)
- All pixels: differences -1.5m to +0.5m
- 2000 random pixels: differences -0.3m to +0.5m
- Differences below -0.5m: 312 pixels of $4.8x10^6$ pixels
- Histogram: SfM-MVS DEM a bit higher than TLS DEM
- Bimodal differences: alignment of TLS clouds



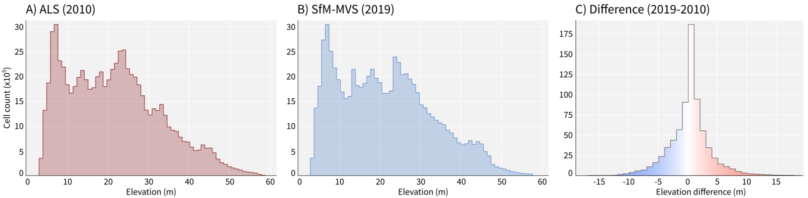
# ALS x SfM-MVS - differences

- #1 - highest positive difference, migration of a large "central dune"
- #2 - accumulation of sand towards a vegetated ridge
- #3 - migration of the dune field over the road



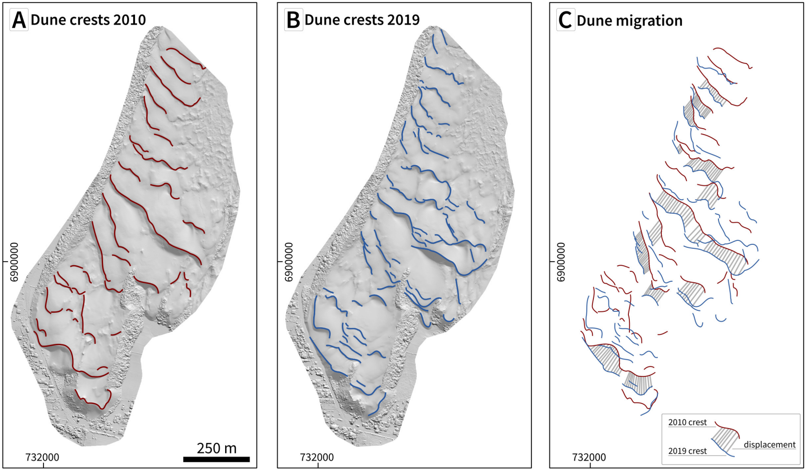
# ALS x SfM-MVS - histograms

- Differences -16.95m to +23.15m, with mean and median ≈0.0m
- Sand volume 2010 (ALS) - 9 035 115.45 m$^3$
- Sand volume 2019 (SfM) - 9 010 844.95 m$^3$
- decrease of 24 270.50 m$^3$ or 0.2%

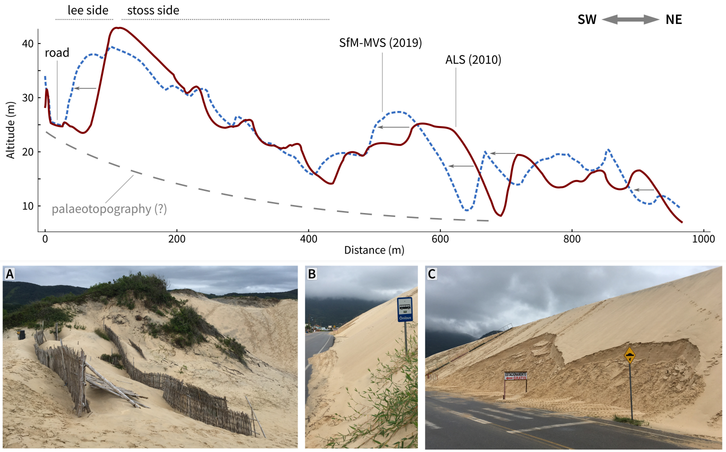


# Dune crests

- Dune displacement - mean azimuth of 215.5°, mean length ≈44.5m
- Displacement rate of ≈5 m/year



# Topographic profiles and photos



## Conclusions

- Image matching was successful in all areas of the survey due the presence of superficial features (footprints and sandboard tracks) and visibility of the sedimentary stratification, highlighted by heavy minerals
- A cloudy sky provided a diffuse illumination, without hard shadows, and the scattered light rain ensured that the sand was humid, without the presence of a layer of loose sand over the dunes, which would mask the stratifications and other features in the photos
- The SfM-MVS DEM was validated against a TLS DEM as reference. The comparison resulted in RMSE of 0.08m and MAE of 0.06m. The TLS DEM has a smooth appearance, with well-marked dune crests and vegetated areas, while the SfM-MVS DEM shows a small-scale roughness that hinders visual identification of small features
- The FPD de-noise algorithm was applied to the SfM-MVS DEM with good results in terms of surface smoothing, without any significant changes in descriptive statistics and error metrics

# Conclusions

- Volumes calculated from the ALS and SfM-MVS DEMs show a difference of 0.2% between 2010 and 2019. Such small variation is within reported uncertainties for SfM-MVS reconstructions and may be related to the installation of sand fences to promote dune stabilization and the constant removal of sand from the road in front of the dune field
- ALS might be acquired in little time, but it is by far the most expensive, imposing a serious constrain on repeated surveys, especially for researchers in developing countries
- TLS has an intermediate cost but it demands more fieldwork and more processing time. In our case we needed three days for the TLS survey and around three weeks of full-time work to produce a DEM of $\approx$80 400$m^2$.
- SfM-MVS is a low-cost solution with fast and reliable results. We were able to cover $\approx$740 900$m^2$ with six RPA missions in under three hours. Processing time in a medium-range workstation was $\approx$13 hours. This makes it an excellent method for 3D modelling and continuous monitoring of coastal dunes.

# Paper

Computers & Geosciences 143 (2020) 104569

Contents lists available at ScienceDirect

Computers and Geosciences

journal homepage: www.elsevier.com/locate/cageo

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## Dune migration and volume change from airborne LiDAR, terrestrial LiDAR and Structure from Motion-Multi View Stereo

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- `https://doi.org/10.1016/j.cageo.2020.104569`
- Preprint available in ArXiv (`https://arxiv.org/abs/1910.06186`)
- Data available via OpenTopography
- Jupyter notebooks as Supplemental Material and in Github

# References

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