TerraceM

A Matlab® tool for the analysis of **marine terraces**

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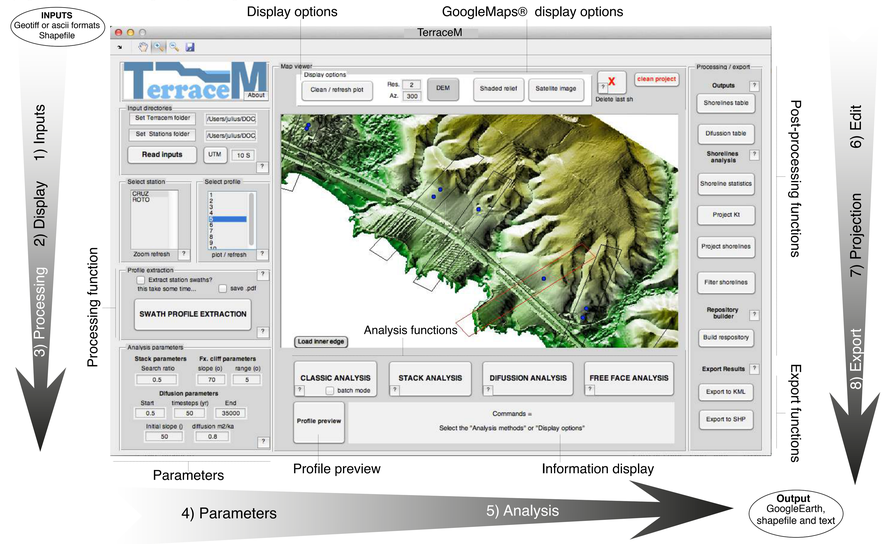
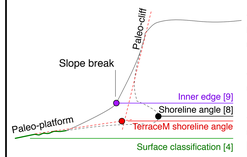
To improve our ability to rapidly assess and map shoreline-angles at a regional and local scale we have developed TerraceM, a MATLAB® tool that allows estimating the shoreline angle and its associated error using high-resolution topography. For convenience, TerraceM includes a graphical user interface (GUI) that displays the topography and online Google Maps® imagery. The analysis follows a workflow that consists of 8 steps:



Terracem approach

Sea-level markers in wave-cut terraces



-There are diverse methods to estimate marine terrace elevation, however some of them are not appropiate to obtain reliable uplift rate estimations when comparing with high-stands [4, 8 ,9].

-The Shoreline-Angle is the geomorphic marker that better represent a past sea-level position and can be correlated directly with sea-level high-stands [8]

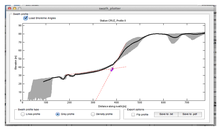
-The Shoreline-angle is an imaginary point difficult to asses, erosion and difussion can mask it position.

-TerraceM explore different methodologies to remove erosional or depositional disturbances that mask the shoreline-angle location.

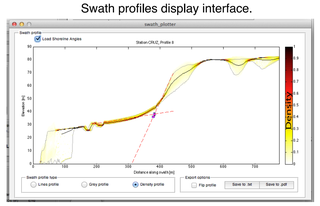
Processing function (Swath profiles)

Swath profiles are generated through rectangular profiles.

The cells enclosed whithin the profiles are projected and classified in bins. Then, mean, minimum and maximum elevations are calculated for each bin.



Swath profiles display interface.



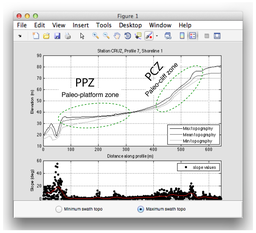
Analysis functions

TerraceM include four functions that use different methods to determine the shoreline-angle in several geomorphic scenarios.

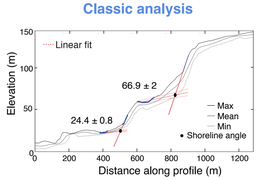
The profiles are analyzed through the shoreline-angle mapping interface using linear interpolations on PPZ and PCZ.

Functions	Application
Classic Analysis	Staircase flights of marine terraces [8]
Diffussion Analysis	Difussion forward modelling [6]
Free-face Analysis	Beach-rock covered or staircase terraces
Stack Analysis	Rough or stacked coasts

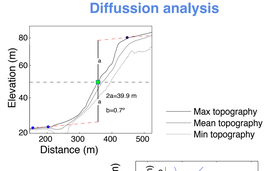
Shoreline-angle mapping interface



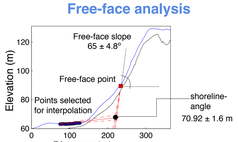
Classic analysis

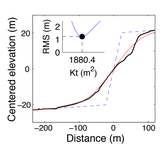


Diffusion analysis

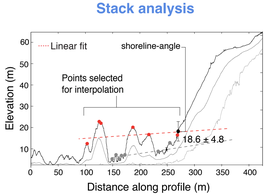


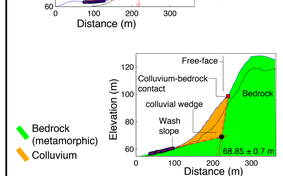
Free-face analysis





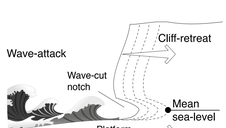
Stack analysis



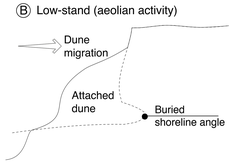


Formation and degradation of marine terraces

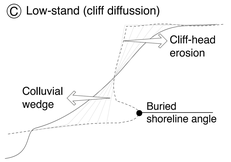
Ⓐ High-stand (wave erosion processes)



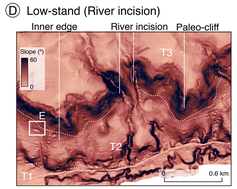
Ⓑ Low-stand (aeolian activity)



Ⓒ Low-stand (cliff diffusion)



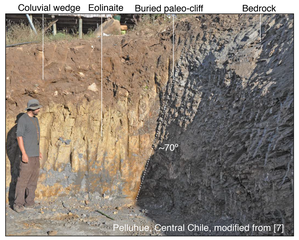
Ⓓ Low-stand (River incision)



Marine terraces are ephemeral planar landforms generated by the effects of sea-level variations and tectonic uplift.

Marine terrace formation occurs during high-stands due sea-level rise and cliff retreat (A).

During low-stands terraces are eroded by river incision (D) or covered by sediments transported along the beach (B, E) or by cliff diffussion (C).



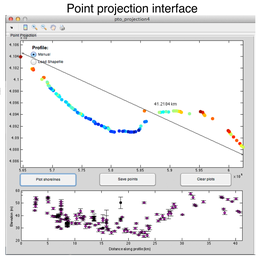
Postprocessing tools and outputs

Point projection:
This routine is used to detect terrace warping by studying shoreline-angles projected along a profile.

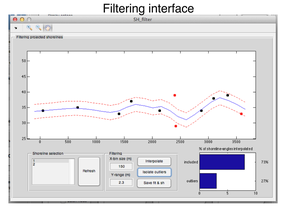
Filtering interface:
Scattered shoreline-angles are interpolated and filtered through this routine.

Export tools:
Shoreline-angles are saved inside a .txt file and can be exported in .shp or .kml formats

Point projection interface



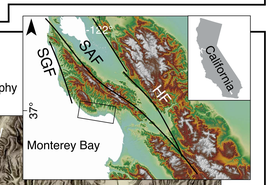
Filtering interface

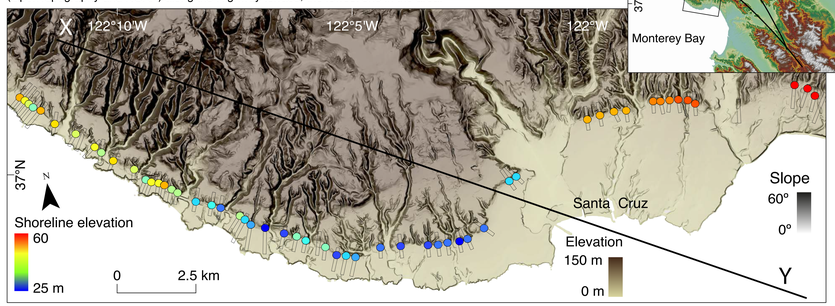


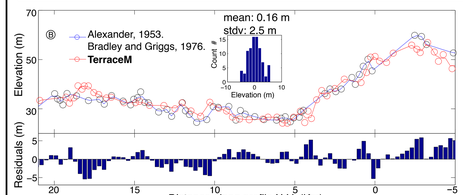
The bin size of lineal interpolations and the range for outliers removal can be adjusted by the user.

Testing TerraceM at Santa Cruz, California

Analysis of marine terraces at Santa Cruz, California, characterized by flights of marine terraces uplifted by several earthquakes along the San Andreas Fault [3]. We mapped shoreline-angles using TerraceM and 2 m LiDAR topography (OpenTopography and NOAA) along the Highway terrace, the lowest one in the area.



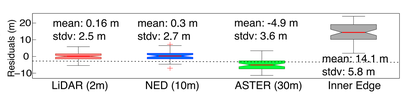




We compared TerraceM results with previous surveys [1] [2] [5], estimating the accuracy and precision of TerraceM measurements through their residuals.

DEM comparisons

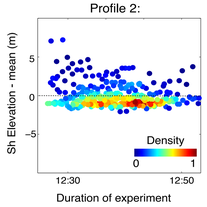
We tested TerraceM using different DEM resolutions (LiDAR, NED and Aster GDEM). We found that precision and accuracy increases as raster resolution decreases.
The high positive residuals of the inner edges indicate that this marker overestimate terrace elevation in comparison with the shoreline-angles, likewise the high dispersion shows that the inner edge is characterized by high dispersion and low accuracy in comparison with the shoreline-angle estimated by TerraceM

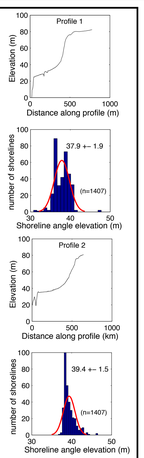


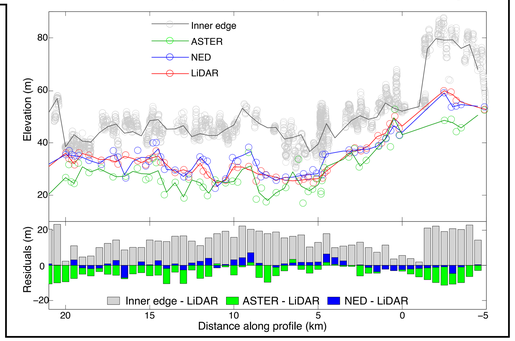
Repeatability of measurements

The methodological approach of TerraceM is relatively simple, however difficulties in estimating the paleo-cliff and the paleo-platform may complicate this procedure and the repeatability of measurements.

To test repeatability, we developed an experiment performed by 10 students measuring shoreline-angles on four topographic profiles during ~20 min.







References

[1] Alexander, C. S., 1953, The marine and stream terraces of the Capitola-Watsonville area, University of California Press, v. 1-4.
[2] Anderson, R. S., and Menking, K. M., 1994, The Quaternary marine terraces of Santa Cruz, California: Evidence for coseismic uplift on two faults: Geological Society of America Bulletin, v. 106, no. 5, p. 649-664.
[3] Anderson, R., Densmore, A., and Ellist, M., 1999, The generation and degredation of marine terraces: Basin Research, v. 11, p. 7-19.
[4] Bowles, C. J., and Cowgill, E., 2012, Discovering marine terraces using airborne LiDAR along the Mendocino-Sonoma coast, northern California: Geosphere, v. 8, no. 2, p. 386-402.
[5] Bradley, W., and Griggs, G., 1976, Form, genesis, and deformation of central California wave-cut platforms: Geological Society of America Bulletin, v. 87, no. 3, p. 433-449.
[6] Hanks, T. C., Buckman, R. C., Lajoie, K. R., and Wallace, R. E., 1984, Modification of wave-cut and faulting-controlled landforms: Journal of Geophysical Research: Solid Earth (1978-2012), v. 89, no. B7, p. 5771-5790.
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[9] Palamara, D. R., Dickson, M. E., and Kennedy, D. M., 2007, Defining shore platform boundaries using airborne laser scan data: a preliminary investigation: Earth Surface Processes and Landforms, v. 32, no. 6, p. 945-953.