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A Simple Method of Measuring Beach Profiles

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ABSTRACT

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Beach profiles provide useful information for coastal monitoring studies and management processes. In 1961, Emery proposed a simple method of beach profiling based on the use of two graduated rods, whose alignment and reading of the intersection with the horizon allow for the determination of differences in level along the profile. In spite of some shortcomings, and because of its simplicity and low cost, researchers and volunteers alike use the "Emery method" in monitoring studies of sand dunes and beaches, mainly in the USA. Modern techniques in current usage are expensive and require specialized technicians.

An alternative method is presented, based on the physical principle of communicating vessels, that consists of the sequential measurement of differential elevation as read on two graduated rods connected by a hose filled with water.

In terms of accuracy, this method compares favorably with standard topographic instruments, having significantly lower costs, higher portability, and greater ease of use and constitutes a valid alternative to the Emery method. It is faster, because the distance between the rods is adjustable to the shape of the beach and to the amount of detail required; does not need a visible horizon, allowing its use in lakes and in situations of limited visibility caused by beach relief or weather conditions; and requires no correction for the Earth's curvature.

The method's simplicity makes it appropriate for use by volunteers in the collection of relevant data for the study and management of coastal zones, contributing to the environmental and scientific education of the participants.

ADDITIONAL INDEX WORDS: *Emery method, coastal zone management, monitoring, environmental education, beach profiling.*

INTRODUCTION

Sandy beaches are dynamic environments shaped by tides, waves, and winds that deposit or remove sediment, thus modeling/changing beach morphology (Andrade, 1998; Bernabeu, Medina, and Vidal, 2003). Regularly monitoring the spatial and temporal evolution of beach profiles provides useful information for the scientific understanding of coastal processes and for management. Traditional topographic equipment, such as alidades and total stations, are expensive and require experienced technicians, restricting their availability to most scientists and limiting their practical value for this kind of study (Komar, 1998). Moreover, researchers working in coastal areas are too few to effectively monitor sandy beaches with the desired regularity in space and time (Hill *et al.*, 2002).

To help overcome this want, in 1961 K.O. Emery presented a simple method of beach profiling based on the use of two rods, marked off in a given unit (feet or centimeters), whose alignment and reading of the intersection with the horizon would allow for the determination of differences in level along the beach profile (Emery, 1961).

This simple "stake and horizon" technique became known as the "Emery rod method" or "Emery boards" and, with slight modifications and improvements (*e.g.,* WHOI Sea Grant Program, 2000), has been in use by both researchers and volunteers in monitoring studies of the dynamics of sand dunes and coastal beaches, mainly in the USA (Hill *et al.*, 2002; Jackson *et al.*, 2000; Komar, 1998).

However, in spite of its obvious simplicity and advantages over traditional surveying techniques (such as portability and cost), the method has some shortcomings, highlighted by Emery himself.

- For long profiles, it requires a correction for the curvature of the Earth's surface (the horizon): when the correction is applied, the true slope is steeper than the measured apparent slope.
- When the horizon is not visible (*e.g.,* in a lake, behind a tall dune, or on a foggy day), the approximate distance to a reference point must be known.
- Errors accumulate because elevation is obtained from the sum of differences of pairs of readings.

Furthermore, in Emery's method, the rods are only 5 ft apart (Emery, 1961), which makes the process needlessly time consuming in long, flat beaches.

An alternative method of beach profiling that shares the advantages of the Emery method over traditional surveying techniques while solving most of its problems has been used for over a decade by the first author.

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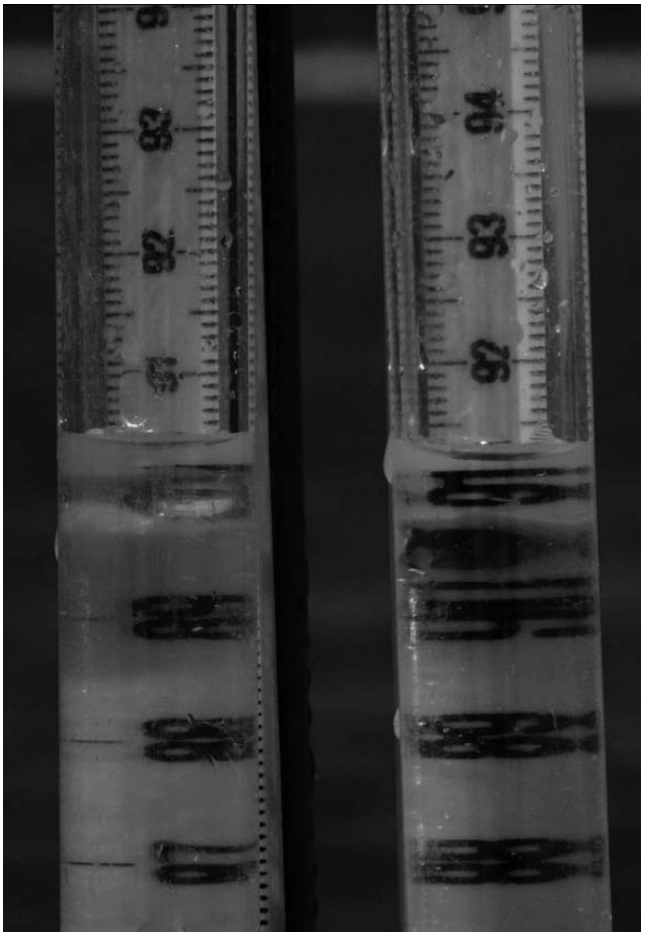

Figure 1. Water in a communicating vessel (hose) forms a horizontal surface. If both ends of the hose are equally graduated and placed vertically side-by-side, readings in water level (approximately 1 cm difference in the example given) correspond to that difference in elevation on the beach.

The method is based on the physical principle of communicating vessels, which states that a fluid in communicating vessels forms a surface in hydrostatic equilibrium. If both ends of a hose filled with water (communicating vessel) are equally graduated and placed vertically side-by-side, different readings of water level in them will indicate differential elevation (Figure 1).

METHODS

Materials

Materials needed include a transparent plastic hose, about 6 m long and 1–1.2 cm in diameter; two transparent acrylic tubes about 1.2–1.5 m long and about 1–1.2 cm in diameter; two graduated poles about 1.2–1.5 m long; plastic cable ties; 5 m of nylon string; and two plastic elbows (90°) with adequate diameter to fit the acrylic tubes and the hose.

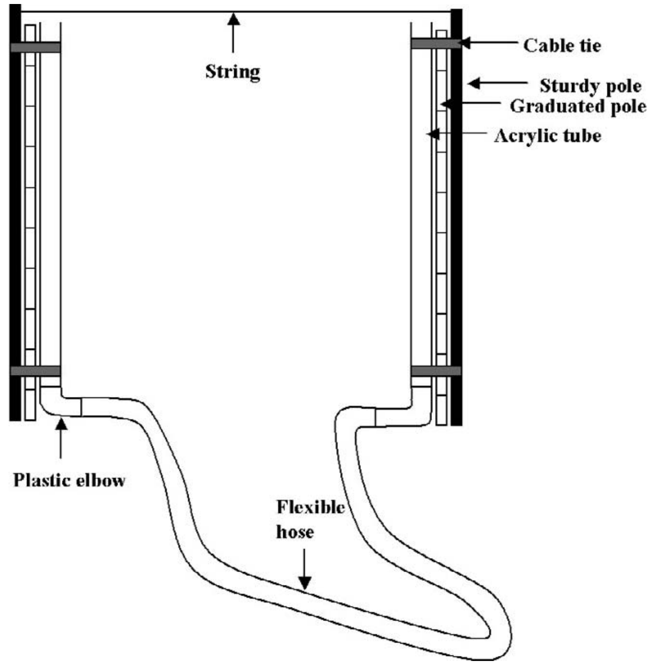

Figure 2. Sketch of equipment used for measuring beach profiles (profiler): communicating vessel (hose, two plastic elbows, and two transparent acrylic tubes), two graduated poles, and, if necessary, two gardening poles for added robustness and stability.

Assemblage

Insert the plastic elbows at the tips of the hose, fit the transparent acrylic tubes at each free tip of the plastic elbows, and tie the tubes to the graduated poles with the cable ties. The plastic elbows enable free water movement and help create a base to prevent the profiler from sinking into the sand. A graduated pole can be made by attaching any kind of measuring tape (sturdy or flexible) to, for example, a gardening pole (Figure 2).

This design can be much simplified. A simpler "profiler" can be built by tying a transparent plastic hose to a pair of graduated poles (*e.g.,* Emery rods). This setup is the easiest and fastest to build but it could (i) lack sturdiness; (ii) cause bends in the hose when the poles are held vertically at ground level, preventing free water movement; and (iii) sink too much in the sand, making readings more difficult (the plastic elbows have that extra advantage).

Operation

Two people are required to measure beach profiles by this method.

The hose is filled with water up to a convenient level (approximately half the height of the poles), measured in both poles standing vertically, side by side. To avoid errors, care must be taken to ensure that no air bubbles are in the hose and that it lies loosely, to ensure free water movement in its interior.

The profile should start at a fixed benchmark (the profile

Table 1. *Comparison of three beach profiles (A, B, C) along the same line made with the profiler and differences between the average of the three profiles (Avg) and total station (TS) readings. Elevations are in negative values because they correspond to vertical differences from the profile anchor.*

Horizontal Distance (m)	Profiler Reading (cm) A		B		C		Elevation (m) A	B	C	Max. Diff. A, B, C (cm)	TS (m)	Avg TS (m)
0	Sea	Land	Sea	Land	Sea	Land	0.00	0.00	0.00	0.0	0.00	0.00
5	109.0	15.0	108.5	16.0	109.0	15.0	−0.94	−0.93	−0.94	1.0	−0.95	0.01
10	112.0	12.0	112.0	12.0	112.0	12.0	−1.94	−1.93	−1.94	1.0	−1.96	0.02
15	104.0	20.0	104.5	19.0	105.5	18.5	−2.78	−2.78	−2.81	3.0	−2.82	0.03
20	93.0	31.0	94.0	30.5	94.0	35.5	−3.40	−3.42	−3.45	4.5	−3.44	0.02
25	85.0	39.0	84.5	40.5	85.5	39.5	−3.86	−3.86	−3.91	5.0	−3.92	0.04
30	88.0	36.0	89.0	35.5	88.5	36.0	−4.38	−4.39	−4.43	5.0	−4.44	0.04
35	93.0	31.0	93.0	32.0	93.5	31.0	−5.00	−5.00	−5.06	5.5	−5.09	0.07
40	90.5	33.5	91.0	33.5	91.0	34.0	−5.57	−5.58	−5.63	5.5	−5.63	0.04
45	81.0	44.0	81.0	44.0	81.5	43.5	−5.94	−5.95	−6.01	6.5	−6.03	0.07
50	83.0	42.0	83.5	41.5	83.5	41.5	−6.35	−6.37	−6.43	7.5	−6.44	0.06
55	75.0	50.0	75.0	50.0	75.0	50.0	−6.60	−6.62	−6.68	7.5	−6.72	0.09
60	72.0	53.0	72.5	52.5	72.0	53.0	−6.79	−6.82	−6.87	7.5	−6.89	0.07
65	61.0	64.0	60.5	64.5	61.0	63.5	−6.76	−6.78	−6.84	8.0	−6.88	0.09
70	56.5	68.5	56.0	69.0	56.5	68.5	−6.64	−6.65	−6.72	8.0	−6.74	0.07
75	62.5	62.5	62.5	62.5	63.0	62.0	−6.64	−6.65	−6.73	9.0	−6.76	0.09
80	103.5	21.0	103.5	21.0	103.5	21.0	−7.47	−7.47	−7.56	9.0	−7.58	0.08

anchor), such as the base of a boardwalk or of a sea cliff, and have an alignment perpendicular to the waterline, whose bearing can be registered with a compass.

The poles are held vertically over the profile line, just touching the surface. Distance between the poles is defined by the length of a string tied to the tip of both poles. Recommended length is 4–5 m.

As soon as water levels in the hose stabilize, both observers read the water level in the graduated poles. The resulting paired readings should be noted on a field table, always ensuring that the order of the readings is kept constant (*e.g.,* land, pole closest to the profile anchor; sea, pole closest to the waterline).

When slopes are high, or where significant changes in the shape of the profile occur (such as at the beach berm, crests, or troughs), the distance between the two poles can be reduced to a half or a quarter simply by folding the string in two or in four, the corresponding distance being noted.

Users progress along the profile line by successively exchanging positions as they move toward the waterline. The last reading should be done when the farthest pole is partially submerged; both the time and seawater level in that pole should be recorded (an average of several waves). This will allow estimation of true elevation of the profile.

Graphing the Profile

The difference between each pair of readings corresponds to the vertical offset in the horizontal distance considered. To obtain mostly positive values (differences), the "land" column should be subtracted from the "sea" column. By this approach, only in places where the beach has a back slope will differences appear as negative values. The overall elevation difference is given by adding the individual vertical differences measured.

The total length of the profile will be given by the sum of the partial horizontal distances defined by the string. Because the string is tied to the tips of the poles, and especially when slopes are high, the string becomes, in fact, the hypothenuse, instead of the horizontal side of the triangle. If more precise results are needed, the Pythagoras Theorem can thus easily be used to calculate the accurate horizontal distance between the two poles.

True elevation can be obtained relating the profile to a benchmark with known *x, y,* and *z* coordinates. If elevation data is not available, the elevation of the profile anchor can be estimated by reference to the predicted tide level at the time of the reading of seawater level.

Assessment of Method's Reproducibility and Accuracy

The reproducibility and accuracy of the method was tested by measuring the same line across a beach three times, with three different pairs of readers. A check on the profiles measured with this method was made with the use of a total station (Leica TCR 307). The results of the check are discussed below.

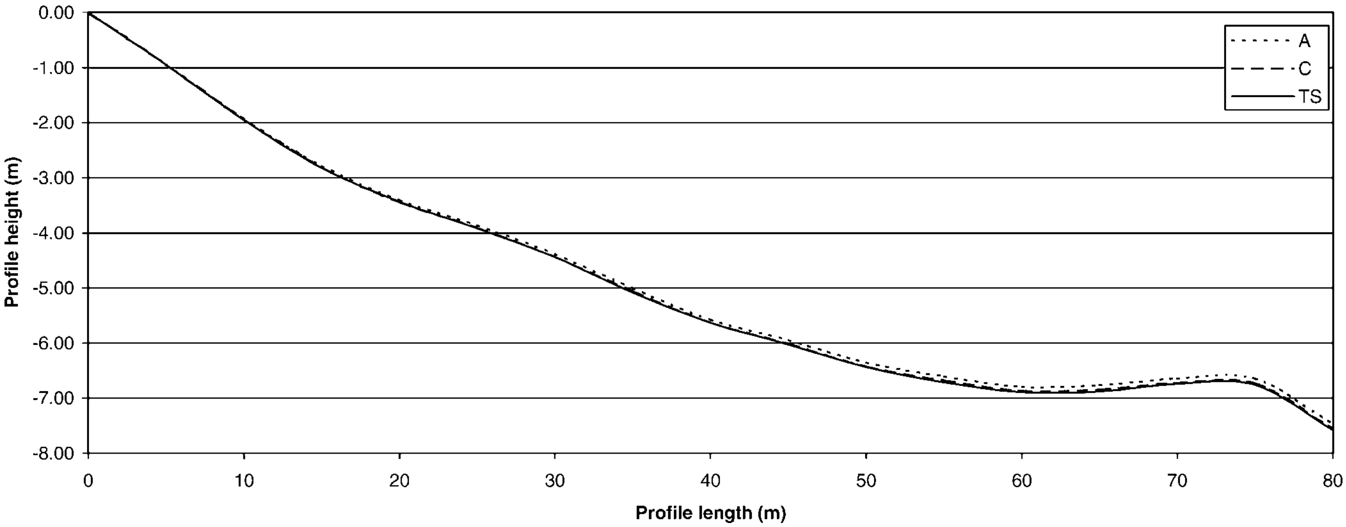

Figure 3. Comparison of beach profiles obtained with the proposed profiler (A and C) and with total station (TS). A relative profile height is presented as a negative value because it corresponds to vertical differences reported to the profile's anchor point.

RESULTS

Table 1 compares the results of the three profiles by this method with the results from the total station. Figure 3 compares the two most different profiles obtained with the present method (A and C), with the profile obtained with the total station (TS).

DISCUSSION

The differences observed between the proposed method and the total station readings are on the same order of magnitude as those reported by EMERY (1961), who recorded differences in elevation of up to 0.17 feet (approximately 5 cm) for his best profile. Differences in elevation on the order of a few centimeters between different profiles are inevitable because the beach surface is not uniform, and microscale crests and troughs are sure to affect the results. Just as with Emery's method, vertical differences generally increase along the profile because of the accumulative tendency of the errors.

The authors have used this method to measure the monthly variation of beach profiles along a stretch of the Portuguese coast over a yearly cycle with very good results (FERREIRA, 2001; FERREIRA and ANDRADE, 2003).

Table 2 briefly summarizes and compares the characteristics of the three methods: total station, Emery method, and the method proposed in this communication.

This method compares favorably with standard topographic instruments, such as alidades or total stations, because of significantly lower costs of acquisition, portability (which translates directly into accessibility to remote areas), and ease of use, related to the amount of previous training necessary for the observers.

It further constitutes a valid alternative to the Emery method because it shares most of its advantages over professional alternatives and overcomes a number of its shortcomings. The method (i) is faster, because the distance between the rods is adjustable to the shape of the beach profile and to the amount of detail required; (ii) does not require the horizon to be visible, allowing the use of this method over a broader range of situations, such as in lakes and in other situations of limited visibility either because of beach relief or weather conditions; and (iii) requires no correction for the Earth's curvature.

Several versions of the apparatus can be built depending on the need for accuracy and on personal taste (or availability of material to manufacture it). One possible improvement is

Table 2. *Qualitative comparison of standard topographic technique, Emery method, and the present method ($ cheap to $$$ Expensive; + low to +++ high).*

	Alidade/Total Station	Emery's Method	Present Method
Cost of equipment	$$$	$	$
Accessibility to remote areas/portability	+	+++	+++
Speed	+++	+	++
Corrections (for greater precision)	Not applicable	Earth's curvature	Slope (horizontal distance)
Visible horizon	Not applicable	Needed	Not applicable
No. of observers	2	2	2
Accuracy	+++	++	++
Amount of training of participants	+++	+	+

the use of a line level to make sure that the string connecting the two poles remains horizontal, thus avoiding the need to correct profile length for slope.

The simplicity of setting up and using the apparatus added to the arithmetic straightforwardness of data analysis makes this method adequate for several kinds of users and for most levels of education.

CONCLUSIONS

The proposed method constitutes a valid alternative to the use of standard topographic techniques and the Emery method in the study of beach profiles. Its major improvement over Emery's method is, perhaps, the possibility of use over a broader range of situations, regardless of weather conditions or ground relief.

The method yields sufficiently accurate data, suitable for scientific and management purposes and to be integrated in local, regional, or national databases.

The ease of setting up the profiler, the use of a simple physical principle, and the straightforwardness of data analysis and graphing make it an ideal tool for multi- and interdisciplinary school projects at various levels of education and for numerous applications.

In Portugal, the method is currently being proposed for integration in the national campaign of the European-wide Coastwatch project as a tool to promote the scientific and environmental education of the participants (mostly students, but also other volunteers, such as coastal residents). By allowing the regular study of large stretches of the coast, it is hopeful that this method will contribute to nourish in its users a sense of stewardship for their coasts.

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□ SUMÁRIO □

Os perfis de praia constituem importantes fontes de informação em estudos de monitorização e em processos de gestão de zonas costeiras. As técnicas topográficas tradicionais são onerosas e requerem o envolvimento de técnicos especializados. Em 1961, K.O. Emery propôs um método simples para a realização de perfis de praia, baseado na utilização de duas varas graduadas, separadas de 1,5 m, cujo alinhamento e leitura da intersecção com o horizonte permite a determinação de diferenças de nível ao longo de um perfil. Apesar de ter algumas limitações, devido à sua simplicidade e custo reduzido, muitos investigadores e voluntários usam hoje o "método de Emery", como ficou conhecido, em estudos de monitorização de praias e dunas costeiras, principalmente nos EUA. Este trabalho propõe um método alternativo, baseado num princípio físico simples: o princípio dos vasos comunicantes, que diz que um fluido em vasos comunicantes forma uma superfície em equilíbrio. Este método consiste na medição sequencial da elevação diferencial lida em duas escalas (ou varas graduadas) unidas por uma mangueira cheia de água (vaso comunicante). A distância entre as duas escalas é dada por um cabo flexível, de comprimento definido (4 a 5 m) que pode ser dobrado duas ou mais vezes para reduzir essa distância e permitir assinalar aspectos particulares do relevo da praia. Este método tem vantagens sobre os métodos topográficos normais, com os quais é compatível, a nível de resultados, nomeadamente por ser muito menos oneroso, mais portátil e muito mais fácil de usar. Também se compara favoravelmente com o método de Emery: é mais rápido (uma vez que a distância entre as varas graduadas pode ser ajustada); o horizonte não precisa de ser visível, como acontece em algumas situações geográficas (como lagos), quando o relevo dunar é alto ou em situações de visibilidade reduzida, como dias de nevoeiro. A simplicidade do método torna-o apropriado para ser utilizado por voluntários, na recolha de dados relevantes para o estudo e gestão das zonas costeiras, enquanto contribui, simultaneamente, para a educação científica e ambiental dos participantes.