A modified equation to calculate the potential future shoreline position using transects

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Introduction

Coastal erosion is an important aspect in shoreline assessment. While process-based models are quite popular for studying shoreline evolution, this study **explores a data-driven alternative** to geometrically **calculate potential future shorelines**.

Existing methods

Transect-based methods are already in use for shoreline analysis for calculating shoreline change statistics (Fig. 1).

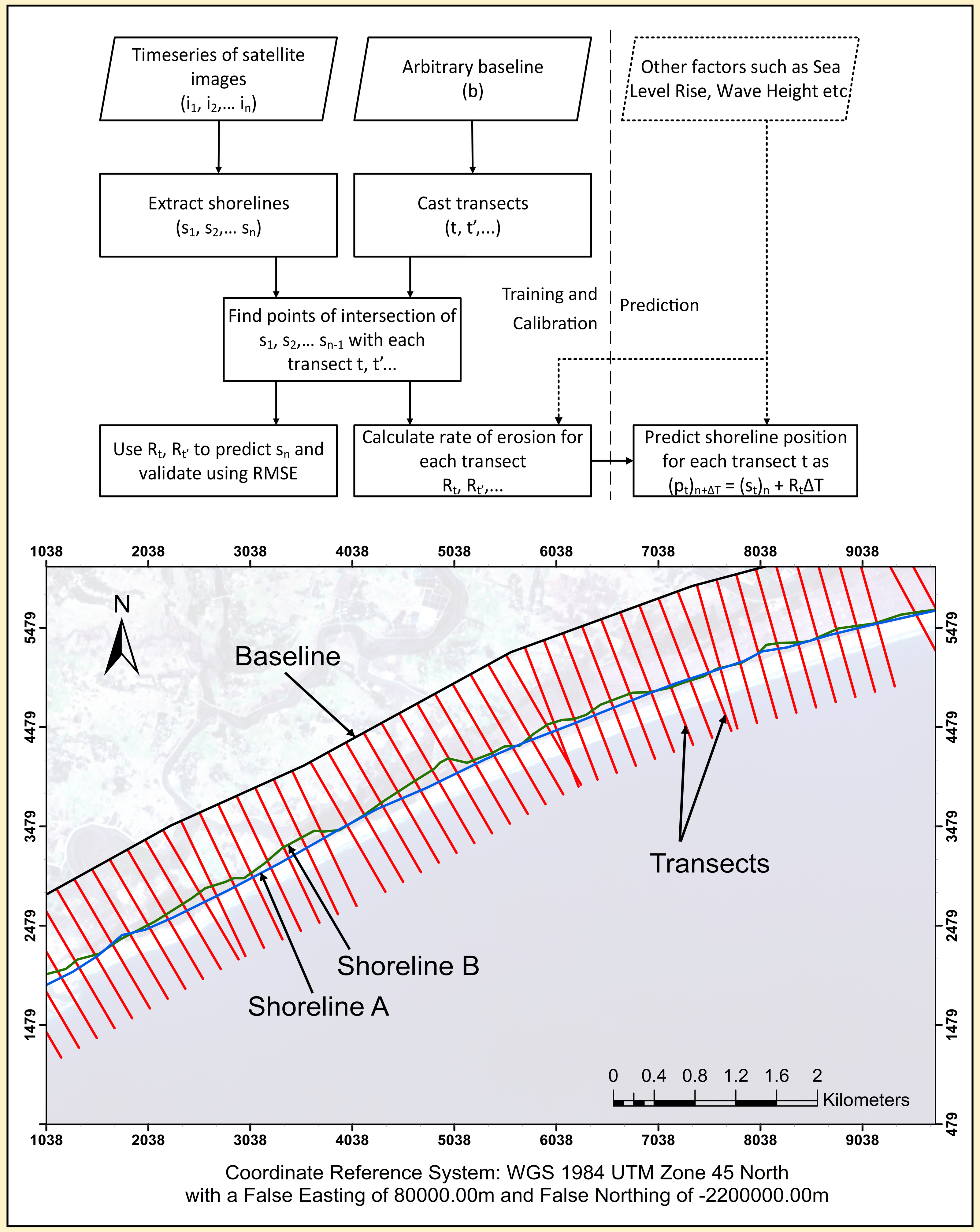

Fig. 1: (a) A typical workflow (top), (b) Illustration of baseline and transects using two shorelines for calculating rate of erosion (bottom)

Developing the modification

Previous studies using a workflow similar to Fig. 1(a) for predicting future shoreline position **did not take into account the orientation of the transects**.

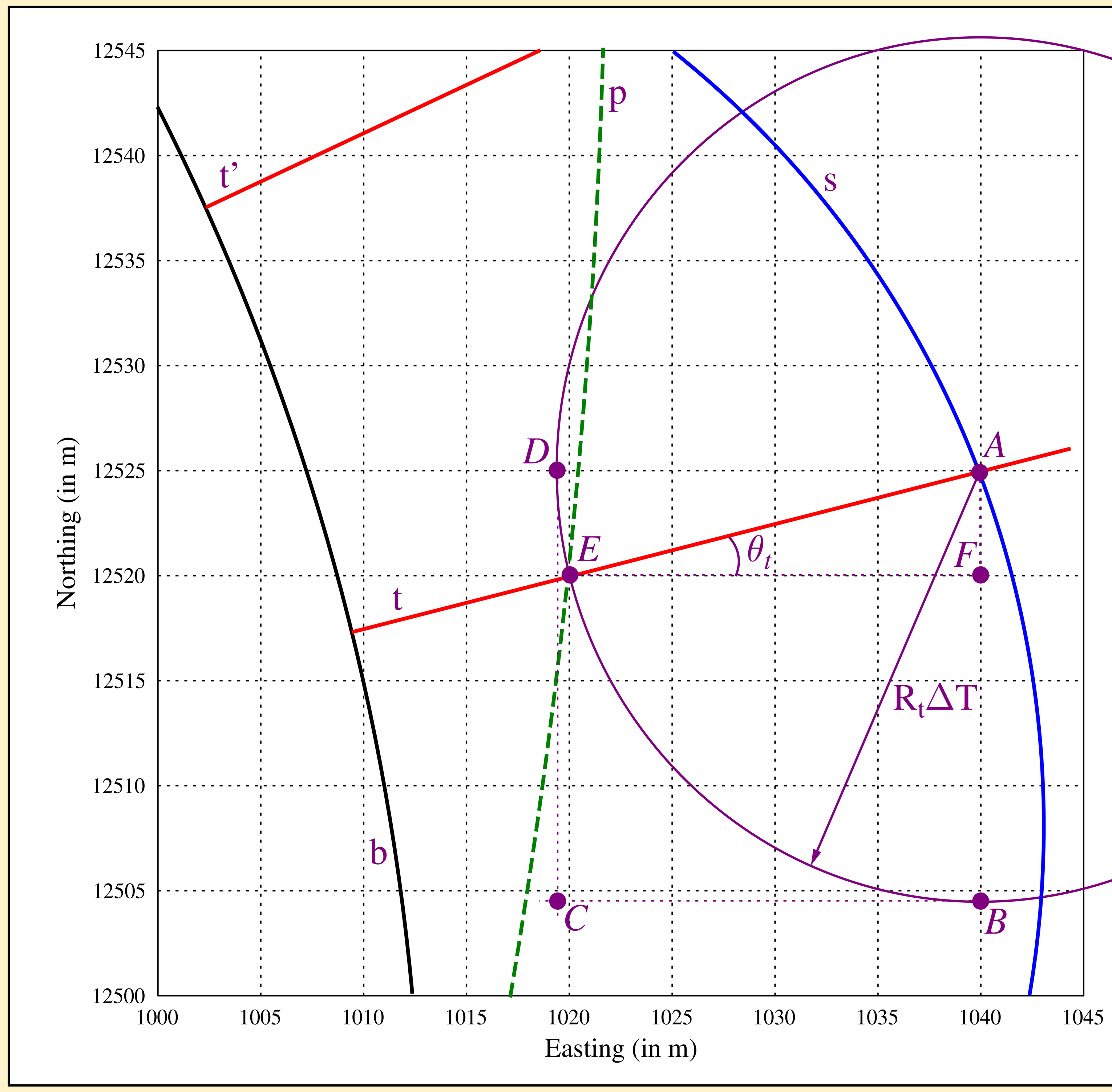

Fig. 2: A transect t intersects the last known shoreline s at A. If the annual rate of erosion for this transect is R_t then the shoreline is expected to move a distance of $R_t\Delta T$ after a duration of ΔT years, indicated by the arc. $R_t < 0$ indicates erosion and $R_t > 0$ indicates accretion

- Adding the distance $R_t\Delta T$ to the x-coordinate of A, y-coordinate of A or both the x- and y-coordinates of A will result in a prediction of points D, B or C respectively — all of which would be erroneous since R_t is calculated along the transect.
- Instead, **the angle θ_t transect t makes with the x-axis of the UTM grid is used to calculate the correct position E** using Eq. 1. E is obtained by adding $R_t\Delta T cos\theta$ (EF) and $R_t\Delta T sin\theta$ (AF) to the x- and y-coordinates of A respectively.
- The predicted shoreline p passes through these points calculated for each transect t, t'….

Resulting equation

The angle **θ_t can be calculated from** the x- and y-coordinates of **the points of intersection of any two shorelines (say s_n and s_{n-1}) with the transect t**. The coordinates of the predicted point p after time ΔT can thus be written as

$$(p_{x,t})_{n+\Delta T} = (s_{x,t})_n + R_t\Delta T cos\theta_t$$
$$(p_{y,t})_{n+\Delta T} = (s_{y,t})_n + R_t\Delta T sin\theta_t$$

where

$$\theta_t = tan^{-1}\frac{(s_{y,t})_n - (s_{y,t})_{n-1}}{(s_{x,t})_n - (s_{x,t})_{n-1}}$$

Eq. 1: Resulting equation to predict future shoreline positions after correction for orientation of transects

Implementation

- This model was **implemented** by [1] and [2] for **predictive shoreline analysis** in Mahanadi delta, India and St. Kitts, St. Kitts and Nevis respectively giving better results.
- **Validation using Root-Mean-Square Error** estimates (Eq. 2) by [1] revealed a **mean deviation of 3.5m over all transects** between the predicted (p) and the observed shorelines (s) for **ΔT = 5 years** resulting in an **improvement of >20%** in comparison to methods without the modification.

$$\epsilon = \sqrt{(p_x - s_x)^2 + (p_y - s_y)^2}$$

Eq. 2: Calculating deviation between predicted and observed shorelines

Discussion and Conclusion

- This study **assumes** that the **trend** and the **cumulative effect of** individual natural and anthropogenic **processes** affecting shoreline erosion **remains unaltered**. These could be removed by including them explicitly in the future.
- Use of a conformal projection is necessary for preserving angles and thus a **Transverse Mercator projection was used**. Distortion of distances are negligible but corrections might be necessary for large study areas.

References

1. Mukhopadhyay, A., et al. "Threats to coastal communities of Mahanadi delta due to imminent consequences of erosion – present and near future." Submitted (2018).
2. Stancioff, C. E., et al. "Predicting coastal erosion in St. Kitts: Collaborating for nature and culture." Ocean & Coastal Management (2017).