Coastal Erosion from Space

Coastal Erosion events:

in Nerja (Spain) *in Kilkee (Ireland)* *in St Laurent mouth (Canada)*

Shoreline Verification and Quality Control

Ref:SO-TR-ARG-003-055-PVR-A3

Date: 01/05/2020

Customer: ESA

Contract Ref.: 4000126603/19/I-LG

This page is intentionally left blank

Applicable and reference documents

Id	Description	Reference
AD-1	Product Validation report	SO-TR-ARG-003-055-009-PVR
AD-2	Shoreline ATBD	SO-TR-ARG-003-055-009-ATBD-SL

Contents

List of Figures

Figure Description **Page**

List of Tables

Table Description Page

1. Shoreline processor Verification

The shoreline processor verification aims to ensure the current shoreline processor conforms to the requirements set out in the Shoreline Processor ATBD (AD-2). The verification testing regime set out is two-part.

Test 1 is a perpendicular distance test it aims to ensure the distances between the waterline and theoretical shoreline conform to the mathematical and scientific theory of water level residual and wave run up outlined in the Shoreline Processor ATBD. A basic geometric waterline with varying metocean /morphological parameters will test each relevant function within the processor to ensure the perpendicular distance between waterline and shoreline is calculated correctly.

Test 2 is geometric position testing. It aims ensure correct shoreline placement and positioning parallel to the waterline. This test will use waterlines from various coastal types at varying scales. This testing is more qualitative than the mathematical testing and includes criteria such as ensuring the observed shorelines are in the correct datum order, no datum intersections and no large line breaks.

Further testing not included in this current version may include general processor stability testing using inputs that do not conform to recognised processor inputs. As the waterline is split into segments within the processor, the perpendicular distance calculation and the geometric positioning are independent processes which do not have any effect on each other.

Test 1 is performed on a control waterline with the following control waterline:

100m of a S2 Waterline, 10m spacing. 130° normal angle of orientation, Projection: WGS84 – 29N, Slope: 3 points. Constant 0.01 dy/dx. Wave Parameters: 0.01m, @ 1s, 130° Incident. Wave Direction.

Test 1, the shoreline perpendicular distance test, consists of a comparison of the distance between a waterline and a corresponding shoreline created from the shoreline processor. This is an empirical value ,ΔL, obtained using the lateral distance equation:

$$\Delta L = \frac{h_{wl} + 0.35\alpha(H_sT_p)^{0.5} + \sqrt{(0.75\alpha(H_sT_p)^{0.5})^2 + (0.06(H_sT_p)^{0.5})^2} \; - h_{datum}}{\alpha} \times (1 - (0.0022 * (\theta_{\boldsymbol{n}} - \theta_{inc}))$$

Where h_{wl} is measured water level, H_S is wave height, T_p is wave period, h_{datum} is the datum height, α is the beach slope, θ_n is the angle normal to the beach, θ_{inc} is the incident wave angle. This equation is a condensed version of the individual equations outlined in the Shoreline Processor ATBD.

The distance measurement is performed by analysing node to node distance between waterline and shoreline through QGIS.

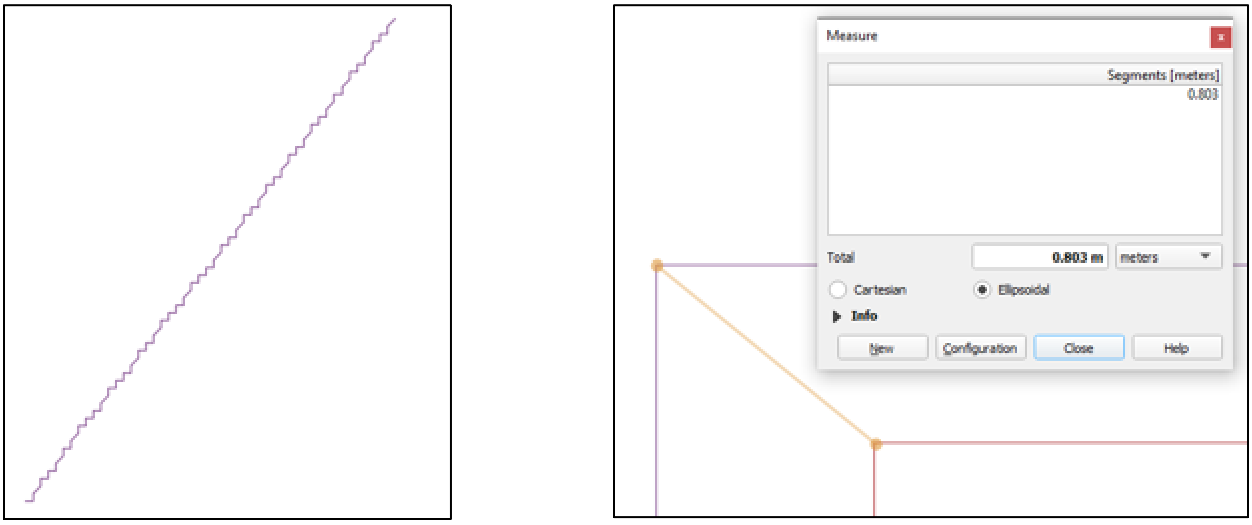

Figure 1.1: Waterline segment used for Test 1 (left). Zoomed in over a pair of nodes with 0.803m distance between the waterline and the shoreline node (right).

The table below details the unit tests performed on the control dataset within Test 1. Each function listed in column one makes up part of the lateral distance equation above. These functions are embedded within the shoreline codebase. Testing these different components with varying inputs individually and together indicates the processor is functioning in accordance with the lateral distance equation. A pass/successful result is granted when the processor inputs create an output that matches the output of the mathematical equation. A ±1% discrepancy tolerance has been allowed, this is to account for rounding errors, minor discrepancies created by the geospatial python packages used, slight beach orientation offset and measurement discrepancies from QGIS.

Table 1.1: Test 1: Perpendicular Distance Testing

Tested Function(s)	**Input**	**Expected Output (Or ATBD requirements)**	**Actual Output**	**Result**	**Comments**
All	Standard	ΔL= 0.80m	ΔL= 0.80m	PASS	
Stockdon2006 GeomCalc	Standard: Wave Period + 10s	ΔL= 7.99m	ΔL= 8.02m	PASS	
Stockdon2006 GeomCalc	Standard: Wave Height + 2m	ΔL= 11.30m	ΔL = 11.32m	PASS	
WaveAngleCalc GeomCalc	Standard: Wave Direction + 45°	ΔL= 0.72m	ΔL= 0.72m	PASS	
WaveAngleCalc GeomCalc	Standard: Wave Direction - 45°	ΔL= 0.72m	ΔL= 0.72m	PASS	
GeomCalc	Standard: All slope+0.1	ΔL= 0.16m	ΔL= 0.16m	PASS	
GeomCalc	Standard: One Slope point + 0.1	End1&2 ΔL = 0.80m Mid ΔL= 0.16m	End1&2 ΔL= 0.80m Mid ΔL = 0.16m	PASS	Slopes are assigned to segments and not interpolated evenly.

GeomCalc	Standard: Water level +1m	ΔL= 100.80m	ΔL = 100.66m	PASS	
GeomCalc	Standard: Datum + 1m	ΔL= -99.20m	ΔL = -99.37m	PASS	

Results from Test 1 indicate the processor satisfactorily calculates node to node distances between shoreline and waterline within a given 1% tolerance. This proves that underlying equations outlined in the ATBD are being adequately reproduced by the processor and gives confidence that the processor outputs are scientifically robust. Further testing regimes may include general stress testing, by using exceptionally high and low values, or more detailed testing by using a wider range of input parameters and in varying combinations.

The table below details the unit tests performed on the control dataset within Test 2. This is to test the placement and positioning of the shorelines. Varying coastal morphologies are outlined in column 1, these include natural morphologies and man-made structures. A by-eye analysis is performed on the outputs in column 2, this considers whether the shoreline positions make sense intuitively, e.g. datums are in the correct order, there is no overlapping occurring, there are no large breaks etc. The result of the testing is either Pass or Fail. Comments justify the result and aim to explain any reasons why the processor may have failed.

Table1.2: Test 2: Geometric Position Testing

Coastal Scenario	Actual Output	**Qualitative Result**	**Comments**
Long Sandy Beach (Red = HAT, Green = LAT datum)		PASS	Lines are continuous and in the correct order. Orientation matches the beach area.

Large Harbour (Red = HAT, Green = LAT datum)		FAIL	Inconsistent placement of shoreline segments. Most likely due to sharp angles and long segment distances combined causing misinterpretation of the shoreline angle. However, these areas are not likely to be needed by users as they are not subject to erosion.
Small Harbour (Red = HAT, Green = LAT datum)		FAIL	Correct placement of shoreline in beach areas. Incorrect orientation and placement around meso-features such as rock groynes. Lack of continuity around areas with sharp changes in orientation. May be remedied with smaller segment length. However, this use case may not be relevant to users.

Rocky Coastline (Red = HAT, Green = LAT datum)		FAIL	Reason for this may be because processor chooses the opposite normal vector direction when calculating line orientation. May be remedied by forcing next line segment to be within an angle range similar to previous segment.Lines are also pushed inland behind coastal structures, this is not possible and is identified as a limitation of the processor.
Groynes (Red = HAT, Green = LAT datum)		PASS	Lines are in correct order, do not overlap, no large breaks or errors created by presence of the groynes.

The results of Test 2 indicate the processor fails to adequately place line segments in rocky cliff areas and areas with complex man-made structures. This is likely due to a large waterline segment length not adequately representing small scales changes in line orientation such as in port areas. Although these areas failed Test 2, these shorelines do not have much practical application and are therefore unlikely to be of interest for end users. Areas subject to erosion such as defended/undefended sandy beaches passed their respective tests, these shorelines have much more utility for coastal management. Fixes to the processor may include using shorter waterline segments, using infinite slope values around man-made structures and using offshore reference points to ensure correct datum placement.

2. Shoreline Quality Control

Quality Control for shorelines is difficult due to a general lack of availability of good quality reference data. Ideal quality control will come from user provided products that indicate the position of the shoreline for comparison. In the absence of these products, it is possible to gauge quality based upon the quality of the input auxiliary data.

Ideal Quality Control measures:

- Shoreline products: User provided shoreline products such as shapefiles that indicate shoreline position. Comparative tests may include creating RMSE values derived from changes in line spacing between the reference and calculated shorelines.
- Nautical charts: User provided nautical charts, especially useful for determining the Highest and Lowest Astronomical Tide shoreline (HAT & LAT). Comparative tests may similarly include creating RMSE values derived from changes in line spacing between the reference and calculated the shorelines.

Other Quality Control measures:

- Analysis of Auxiliary data: For each area analysed, each piece of auxiliary data used to construct the shorelines is reviewed and rated based upon it's quality and applicability. Higher ratings indicate better quality auxiliary data and therefore better confidence in the quality of the subsequent shoreline. For example, shorelines derived from nearby observed data are far superior in accuracy to shorelines derived from coarse modelled data.
- By eye analysis: The quality of the products will also depend on qualitive factors such as line continuity and lack of erroneous data such as offshore artefacts, although these are generally inherited as errors from the waterline processor. This can be done across different coastline types and different met ocean conditions to test the shoreline accuracy.

The datasets used by the shoreline processor are recorded in the shoreline metadata, this information can be used to review the inherent auxiliary data quality and the auxiliary data uncertainty values to understand the quality of the derived shorelines.

End of Document