Sentinel-1 observation for shoreline delineation applied to Mexico's Coast

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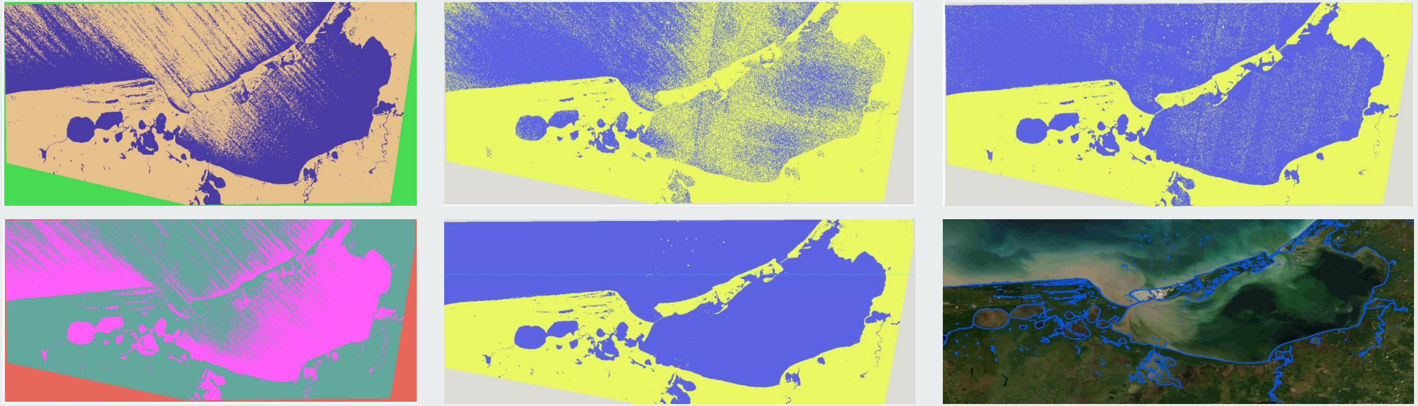
Jorge Paredes Tavares



March 22, 2023 - Valparaíso, Chile

Introduction

- The natural shoreline is a dynamic environment and it is subject to constant weather variability.
- There is a need to monitor of coastal ecosystems for the conservation of coastal vegetation, water and landform (Ward et al. 2020).
- Fragility of coastal ecosystems (erosion, accretion).
  - Sea level changes due to climate change.
  - Seasonal variations.
  - Hurricanes.
  - Tsunamis.

Introduction

- At a country or continental scale, only a few datasets have been developed.
  - Landsat data (Sayre et al. 2019; Bishop-Taylor et al. 2021).
  - Sentinel-2 (Bergsma and Almar 2020).
  - Mainly over an annual time period.
  - Shoreline layer of Mexican Republic (2011-2014) (CONABIO, 2018).
  - SPOT images, covering the 66% of the Mexican coastline (Valderrama-Landeros et. al., 2019).
- In many zones of the Mexican coast, clouds coverage limits the monitoring using optical satellite images.
- Clouds are transparent to SAR, do not affect shoreline extraction.

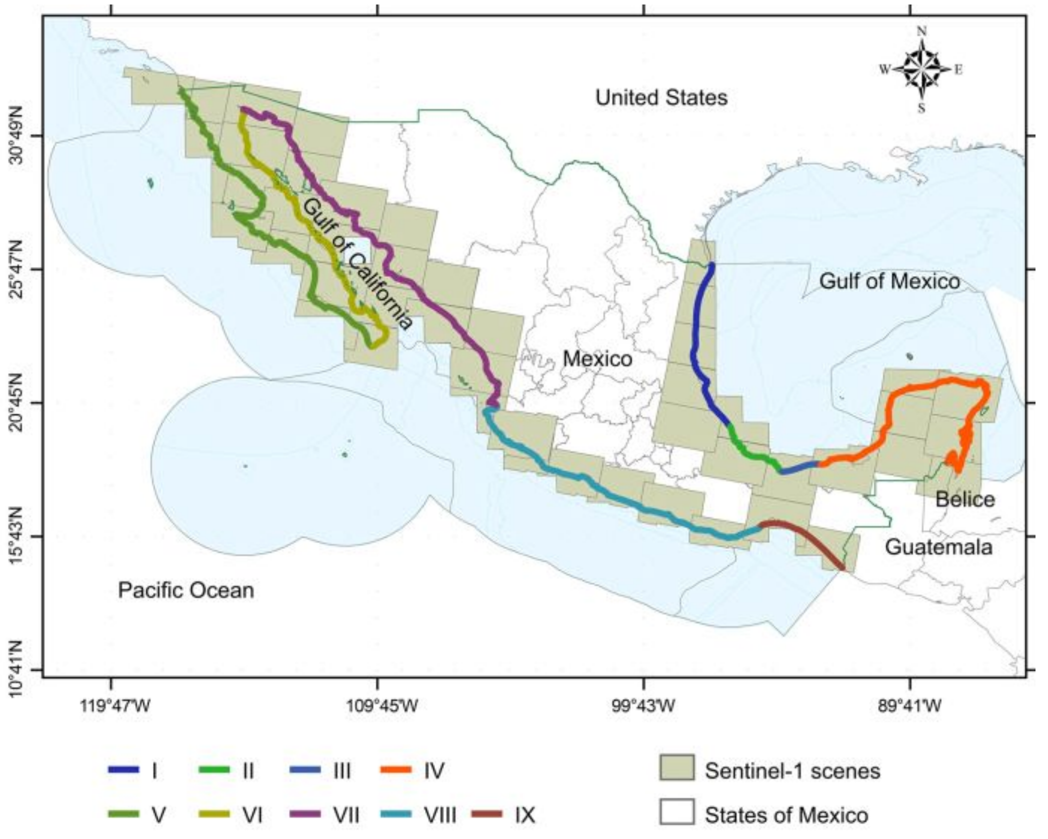
Aim and scope

- Develop a shoreline extraction method to delineate the ocean-land interface through the use of Sentinel-1 data for monitoring the coastline in Mexico.

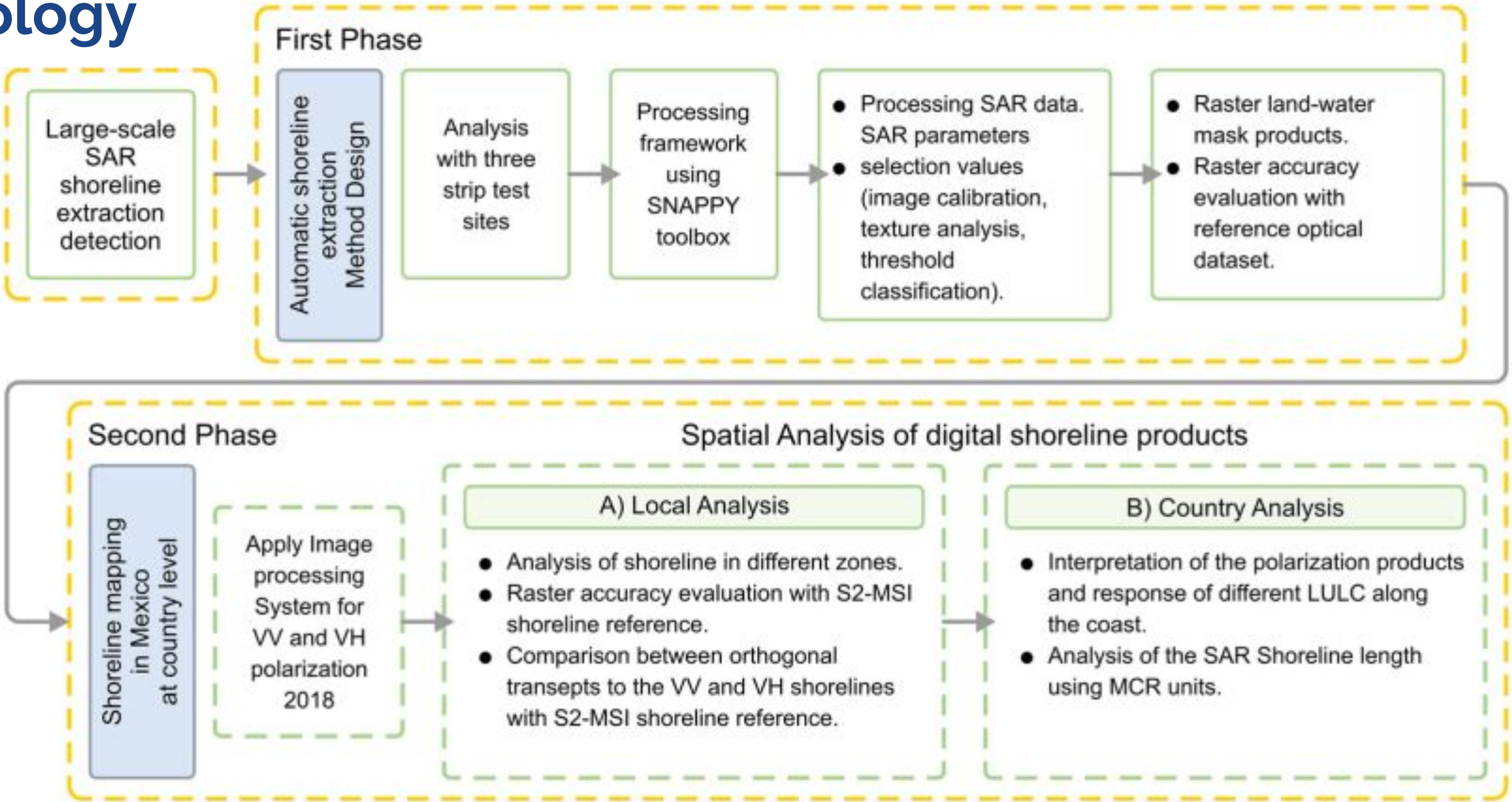
- Design an automated process using GLCM-mean texture information to increase improvements in image binarization by Sauvola thresholding.

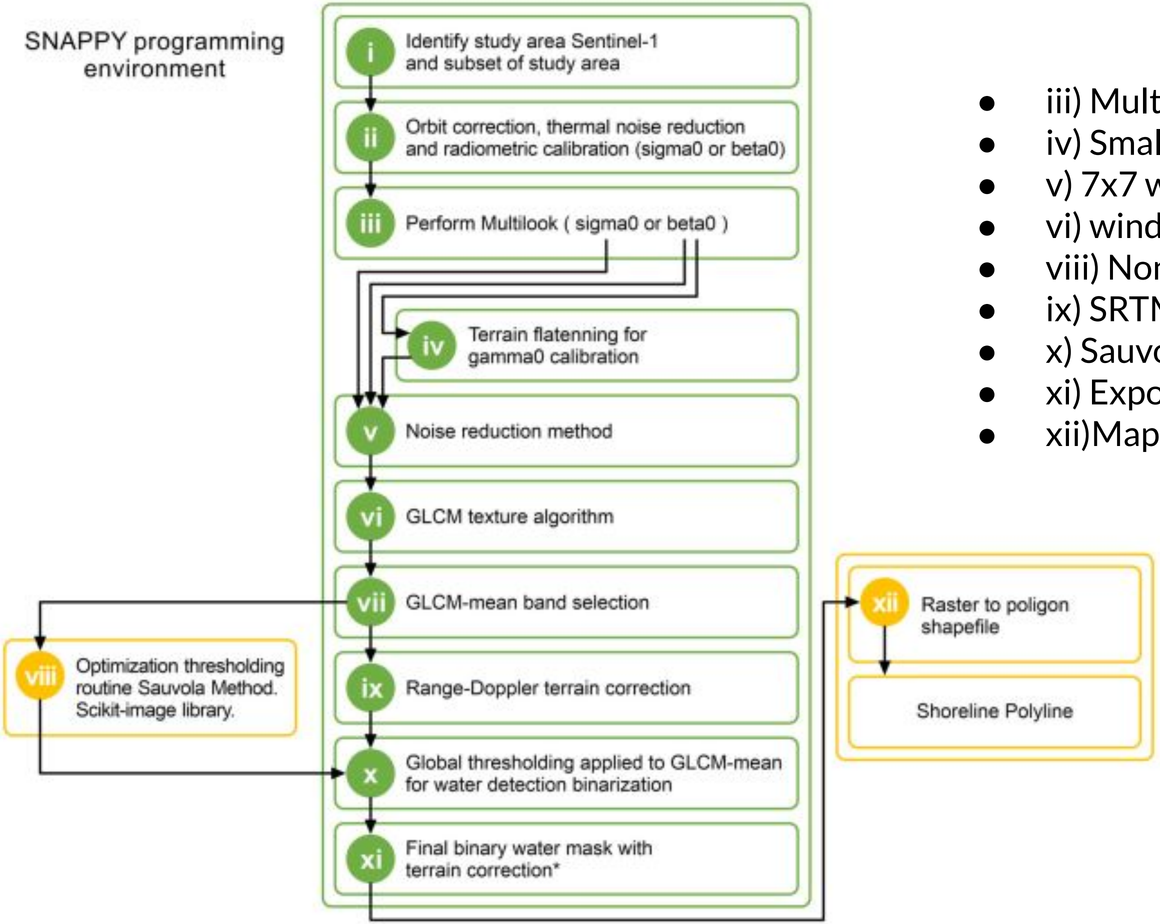
Mexican Shoreline

- Over 9 300 km of coastline.
- Different ecosystems and geoforms.
- Geographic variables such as latitude, geological evolution, climate.



Methodology

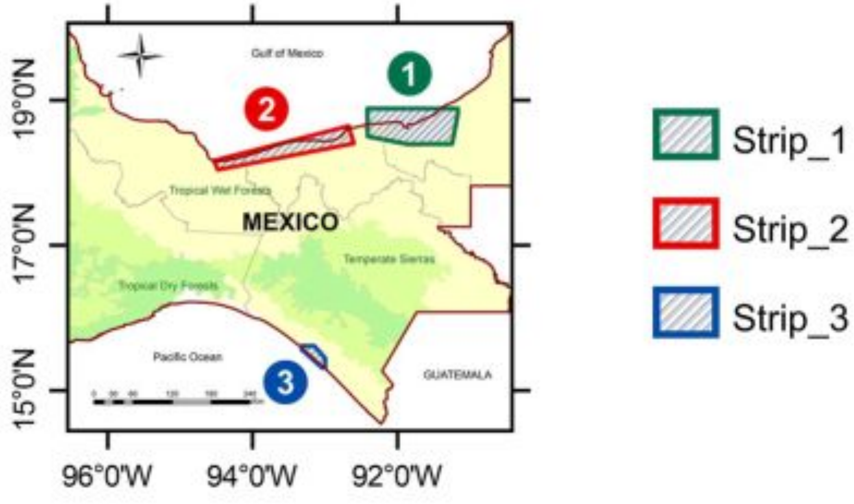




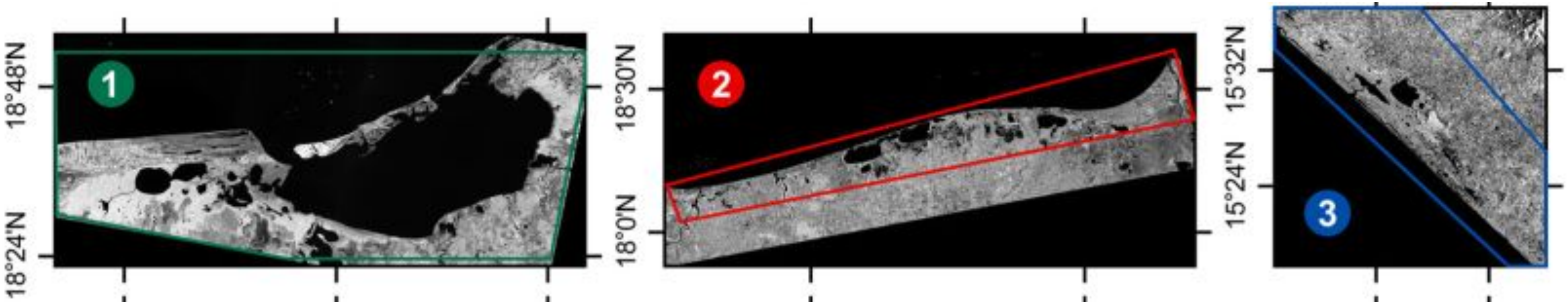
Workflow

- iii) Multilook
- iv) Small model - decreases geometric distortion
- v) 7x7 window damping factor=2
- vi) window 9x9 - 128 bin.
- viii) Non-water = 0, water = 1.
- ix) SRTM-1. Reproject slant range to map space (10 m).
- x) Sauvola threshold.
- xi) Export to tif format.
- xii)Map shoreline generation

Location of three strip test sites



- High resolution images (SPOT).
- SPOT, Sentinel-1 & Sentinel-2: max 4 days of difference.
- Sea level monitoring stations.



Texture calculation

GLCM-mean is used to reduce noise.

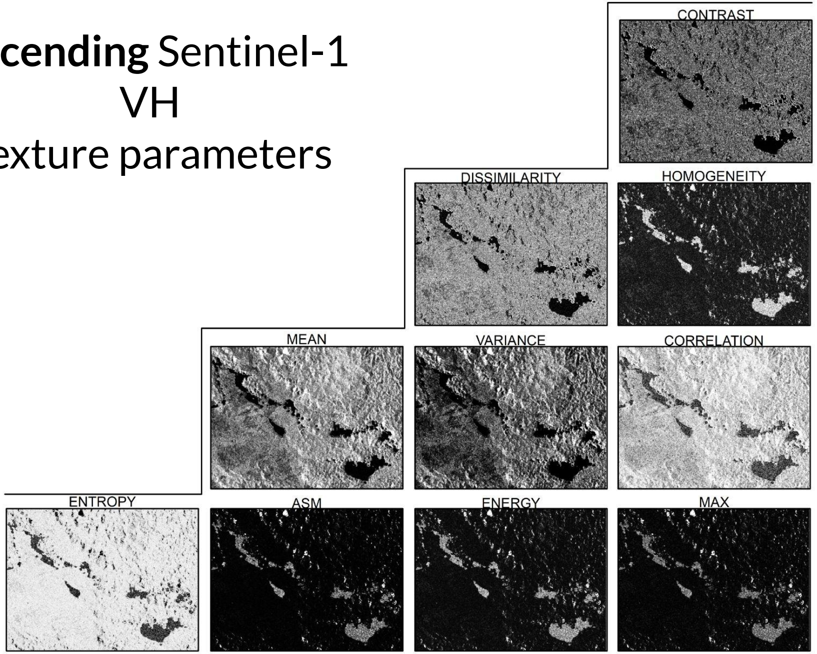
The pixel value is weighed by its frequency of appearance, combined with a determined neighboring pixel value.

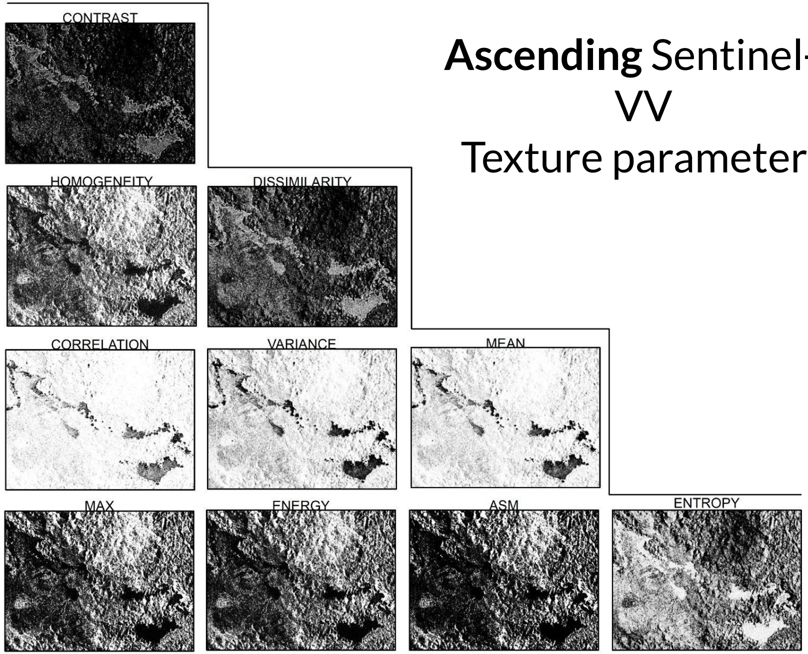
$$\mu_D = \sum_{i,j=0}^{N-1} D(P_{i,j})$$

where μ is the mean, *Pi,j* is the probability of values *i* and *j* occurring in adjacent pixels within the window defining the neighborhood. D (directional) is *i* or *j* (columns and rows).

GLCM texture feature analysis

Ascending Sentinel-1
VH
Texture parameters



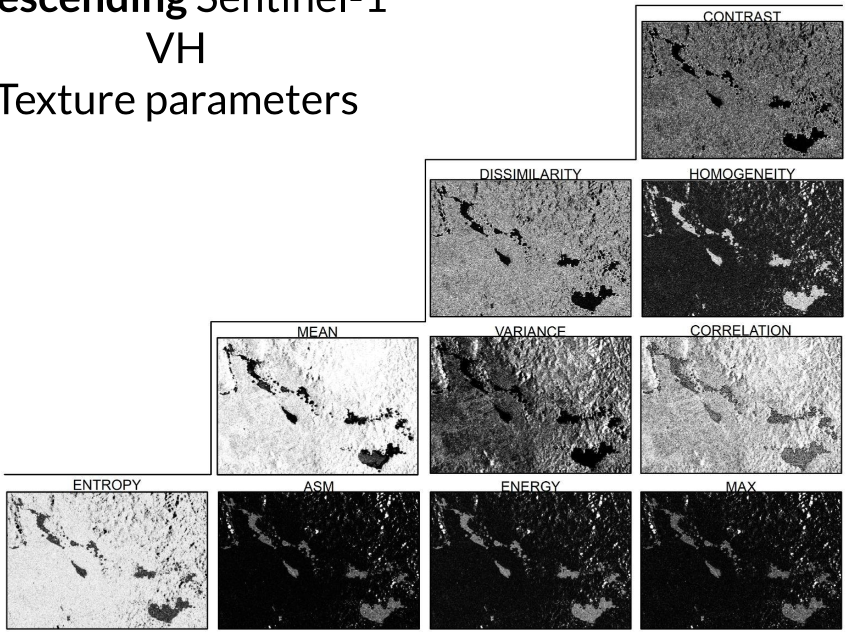


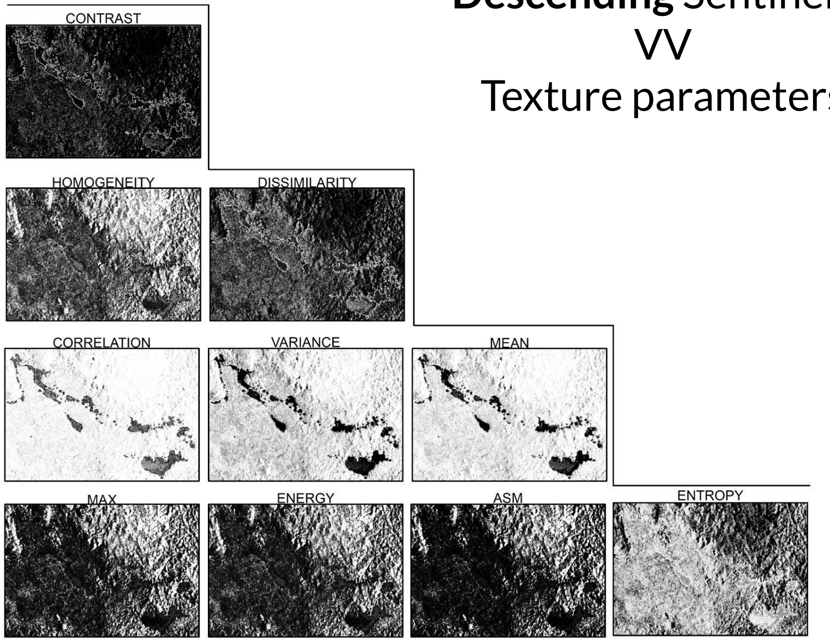
Ascending Sentinel-1
VV
Texture parameters

Texture describers help to better outline water bodies since they are good estimators in the identification of edge contrasts among classes.

GLCM texture feature analysis

Descending Sentinel-1
VH
Texture parameters





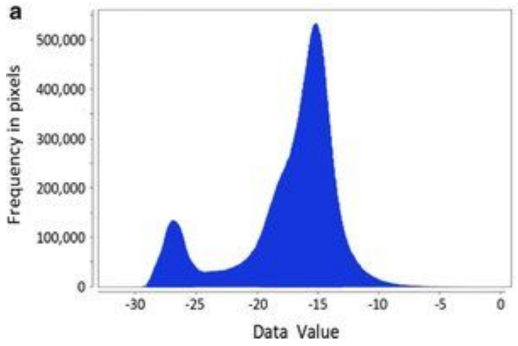
Descending Sentinel-1
VV
Texture parameters

Source: AA López-Caloca, B Escalante-Ramírez, P Henao, Journal of Applied Remote Sensing 14 (3), 036503-036503

Shoreline classification algorithms

Background - Land class. Water - Object.

Bimodal distribution.



Jing-Bo Xue, et al., 2021.

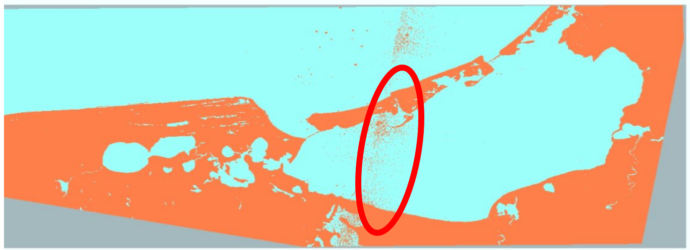
Sauvola Method

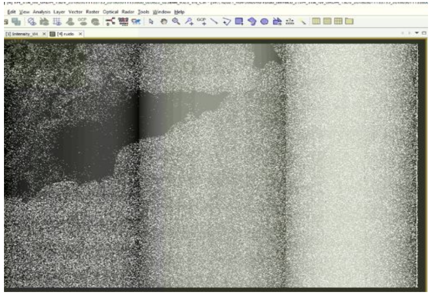
the threshold $T_{sauv}(x,y)$ is determined by means of the average and the standard deviation of the pixel values in backscatter coefficients at location (x,y) within a neighborhood defined by a window of size (w x w).

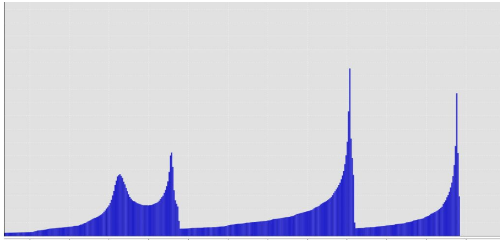
$$T_{sauv}(x,y) = m(x,y) \cdot \left[1 + k\left(\frac{s(x,y)}{R} - 1\right)\right]$$

m(x,y): arithmetic mean
s(x,y): standard deviation
R: max SD of a backscattering coefficient
k: thresholding parameter [0.2, 0.5]

Polarization an thermal noise

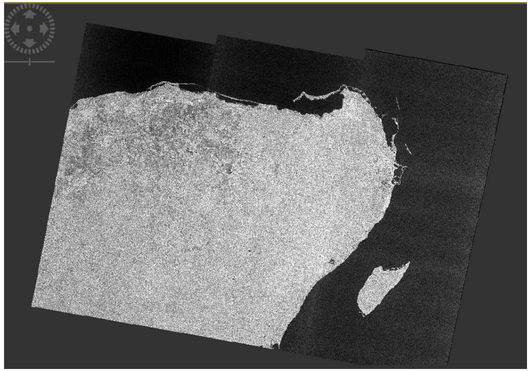




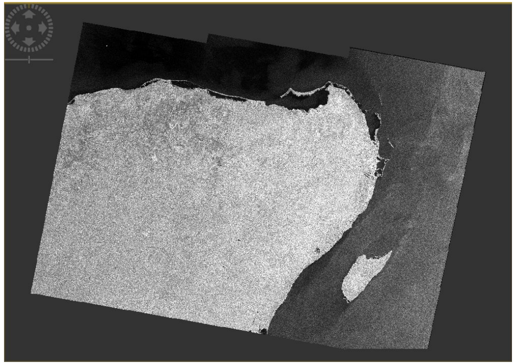


VH sensibility by thermal noise.

Cross polarization channels are significantly perturbed by thermal noise due to wicker power.



2018-03-03



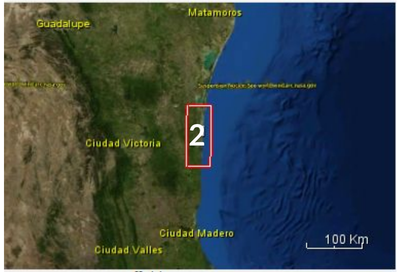
Sentinel-1A
VH polarization

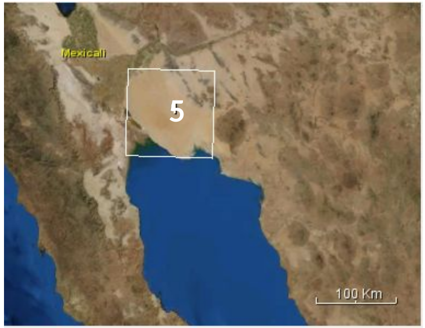
Sentinel-1A
VV polarization

Results

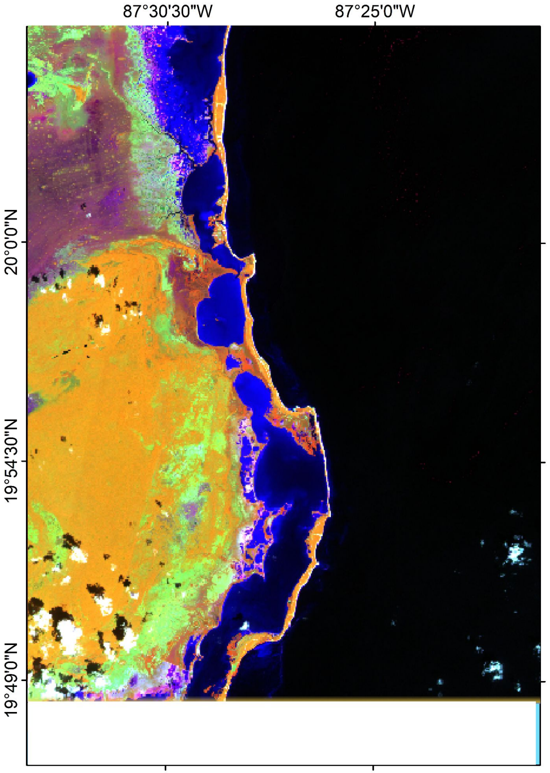
Comparison with S2-MSI and Sentinel-1 shoreline binary mask

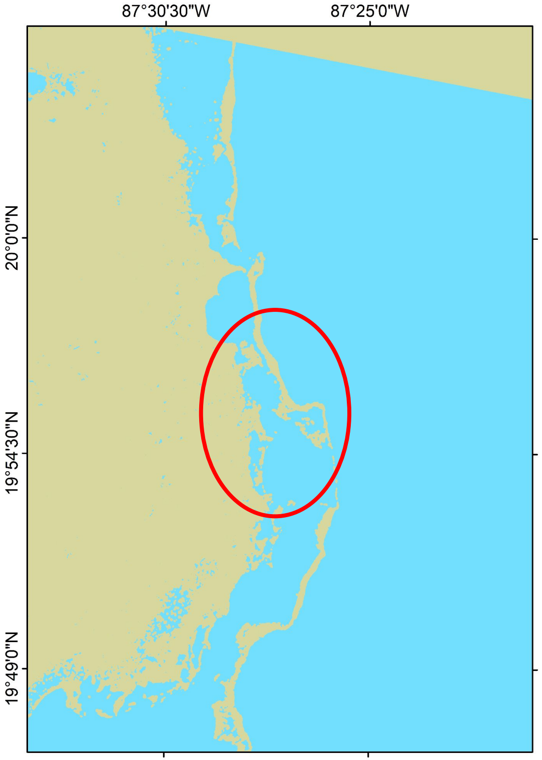
Land-water visual evaluation



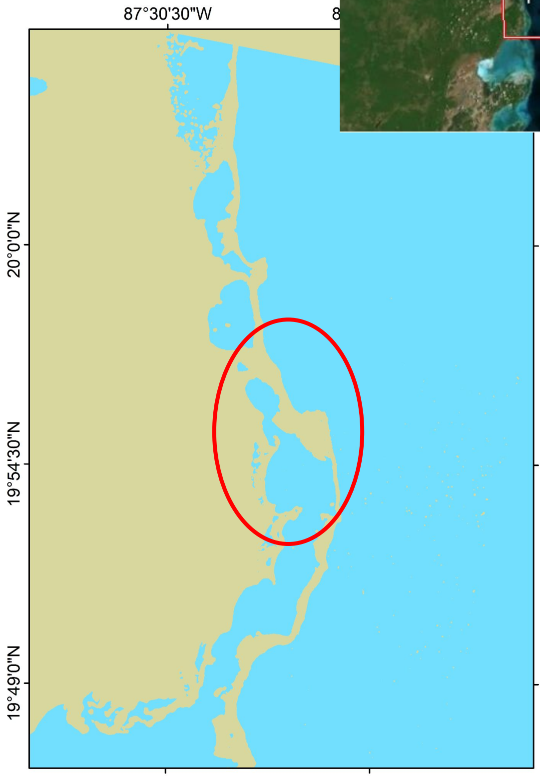


Sian Ka'an Biosphere Reserve - Quintana Roo



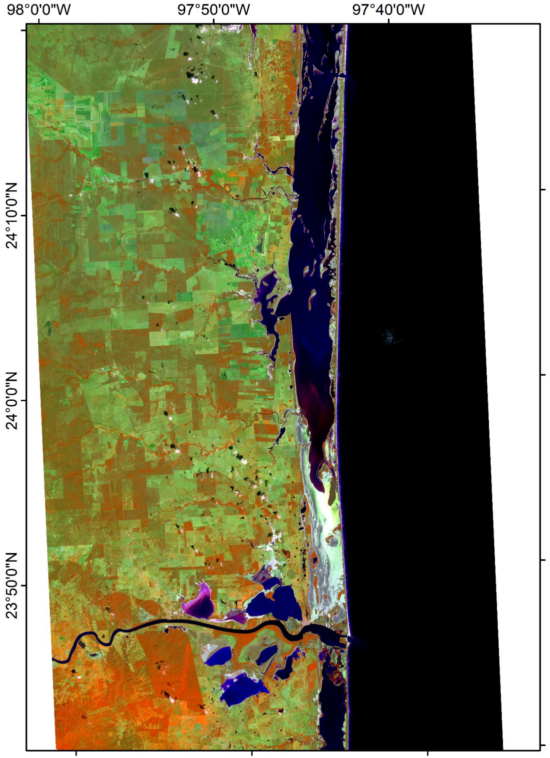


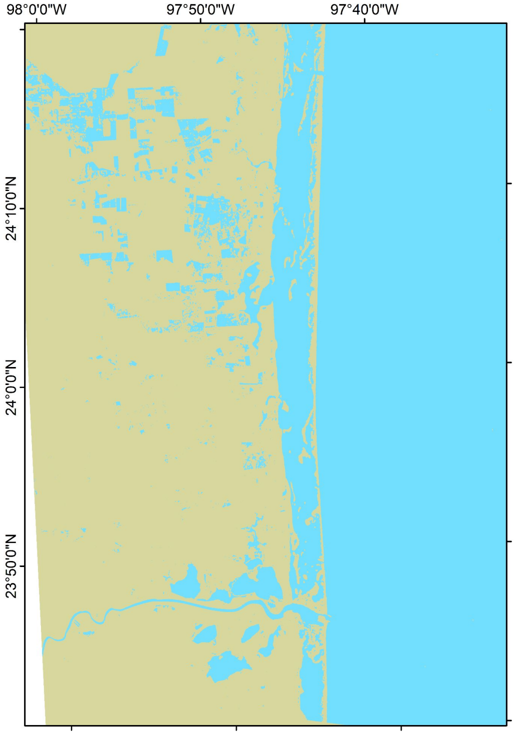
VH



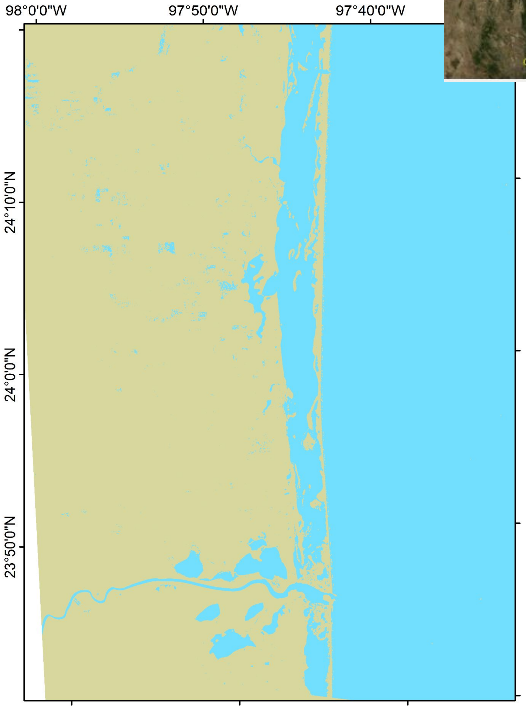
VV

La Pesca - Tamaulipas



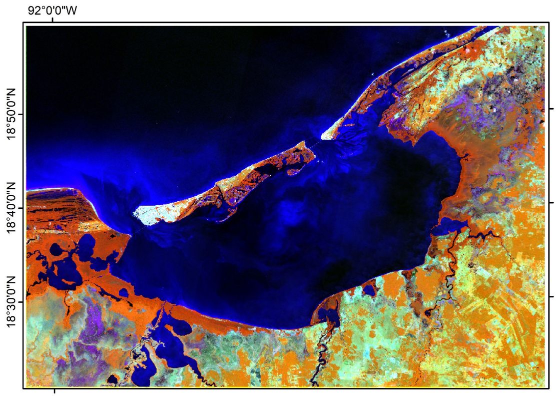


VH

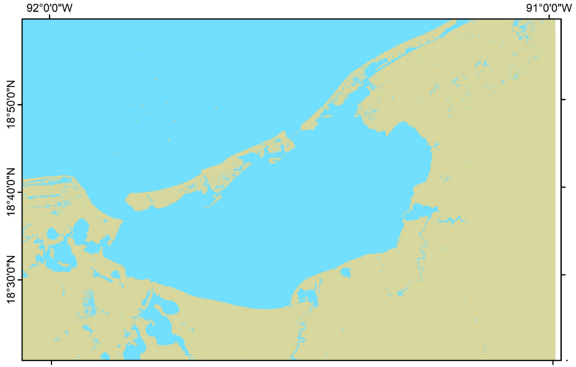


VV

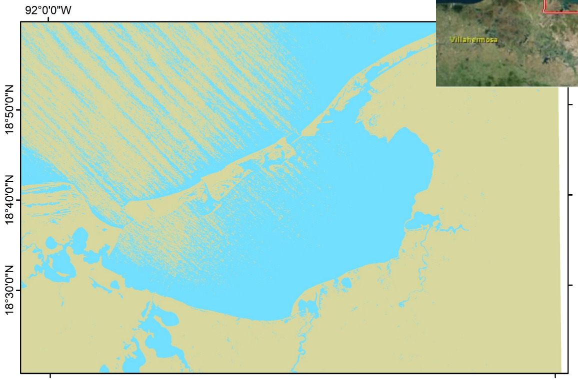
Términos Lagoon - Campeche



Sentinel-2



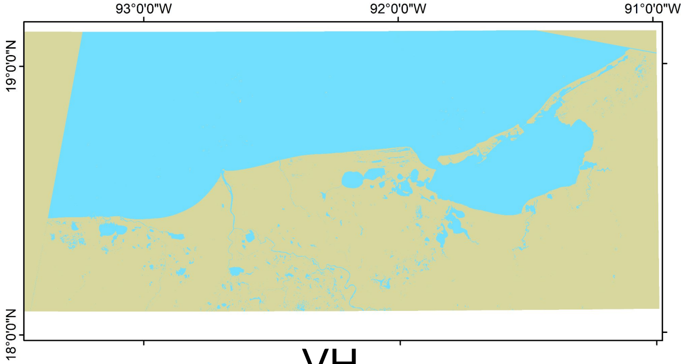
Sentinel- 1 (VH)



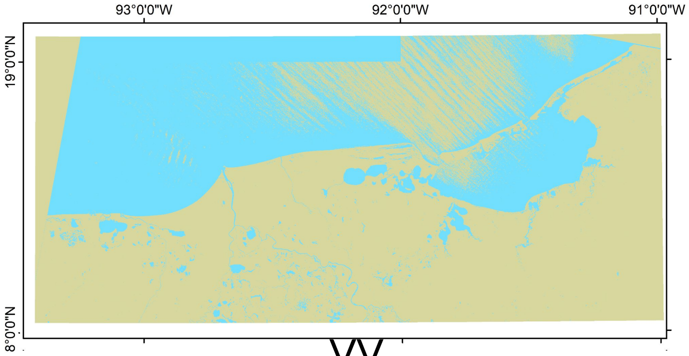
Sentinel-1 (VV)

No water

Water

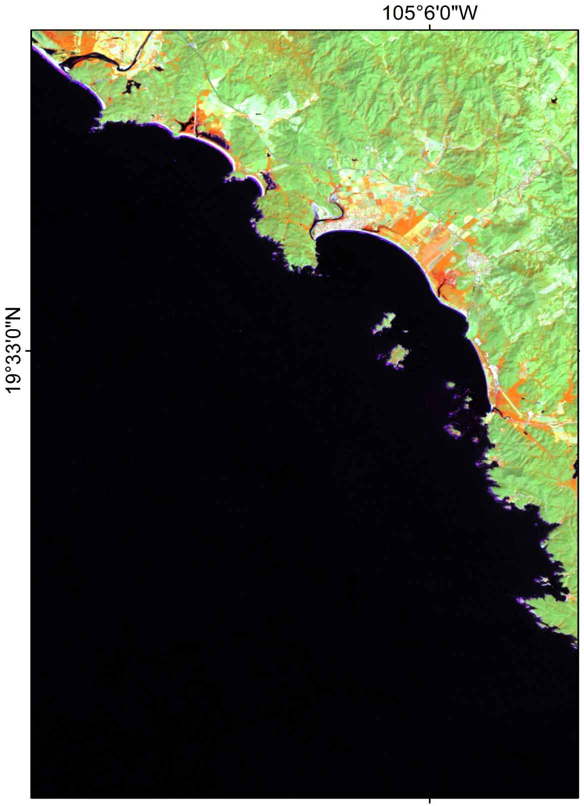


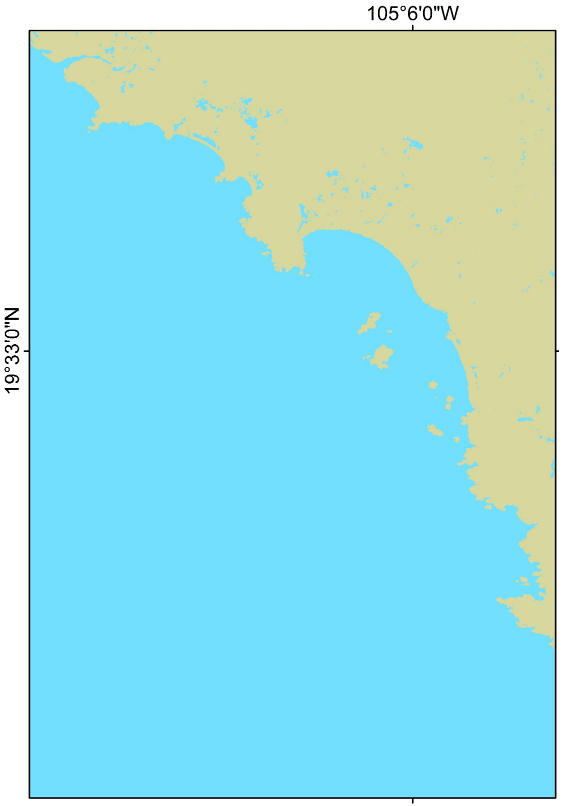
VH



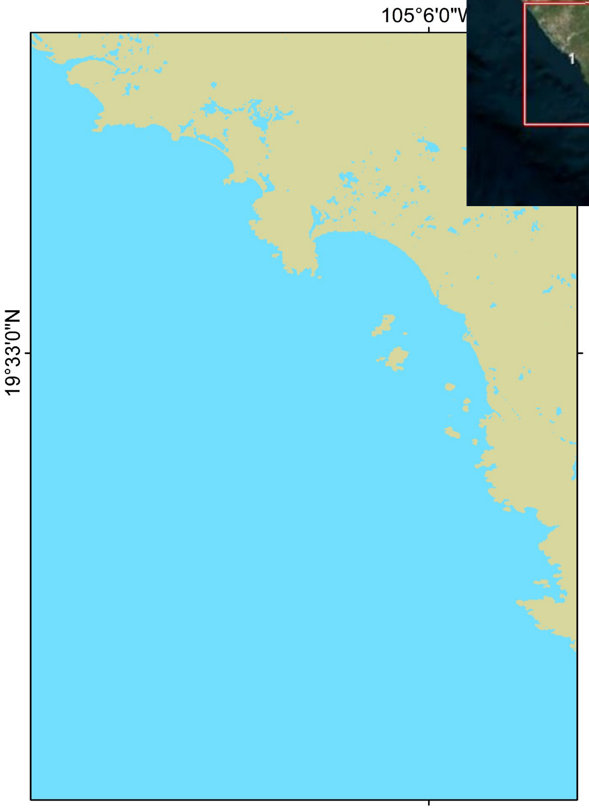
VV

Chamela Bay - Jalisco



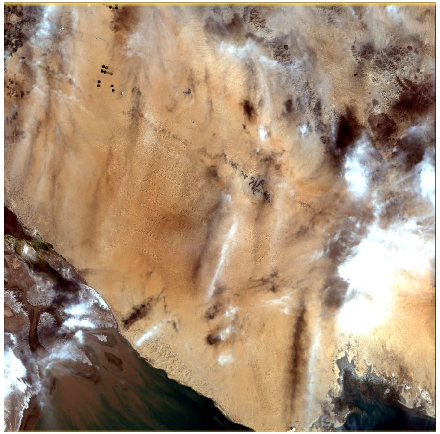


VH



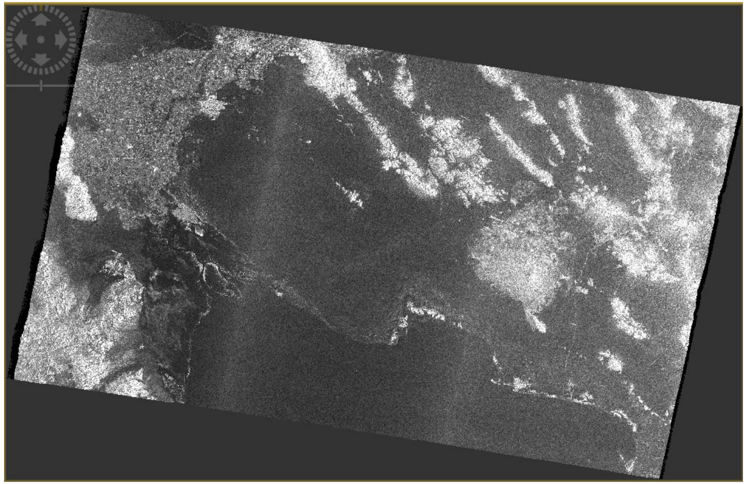
VV

Gran Desierto de Altar - Sonora

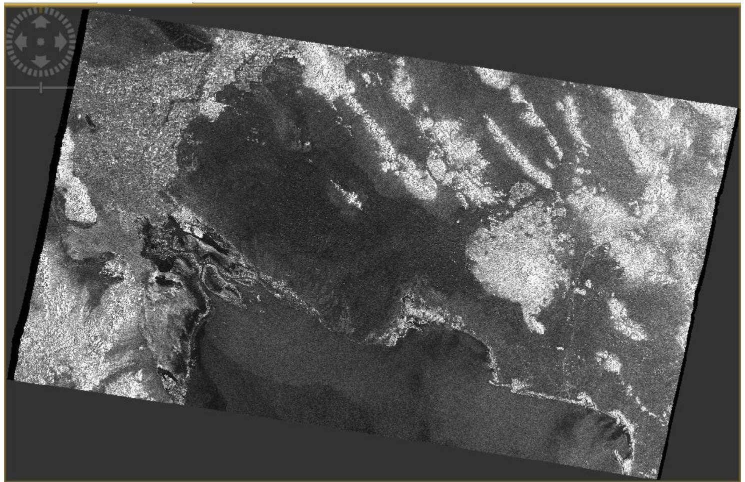


Sentinel-2 MSI Natural Color B4, B3, B2

Sentinel-1 VH



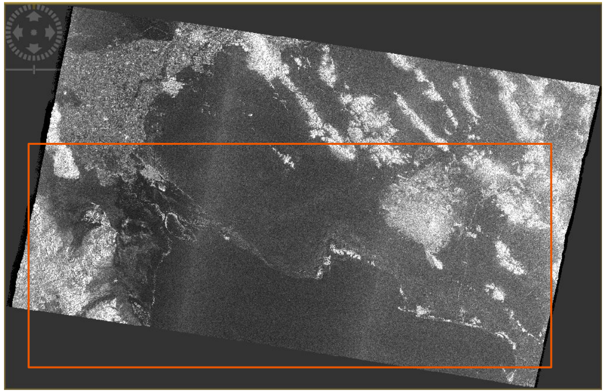
Sentinel-1 VV

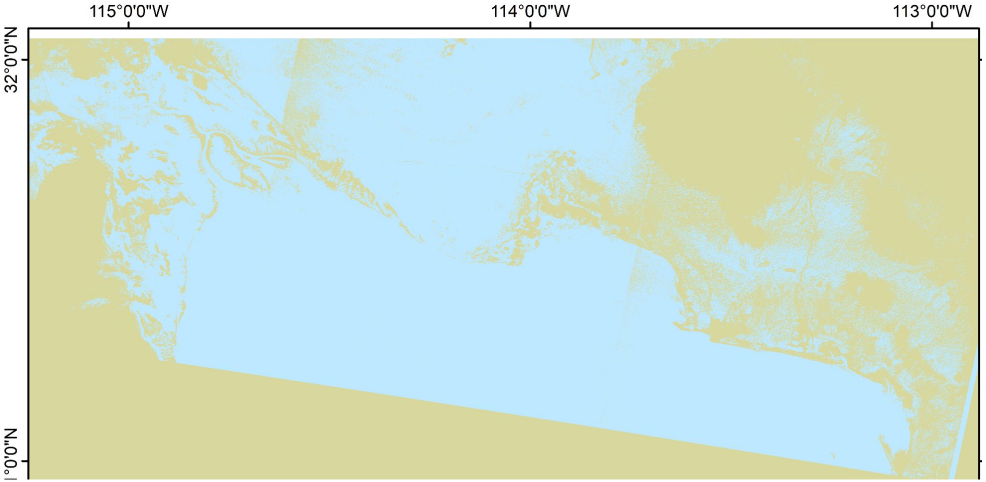


CONACYT Consejo Nacional de Ciencia y Tecnología
CentroGeo 19°17'30"N 99°13'17"O 2489m
Copernicus Relays
JNCC

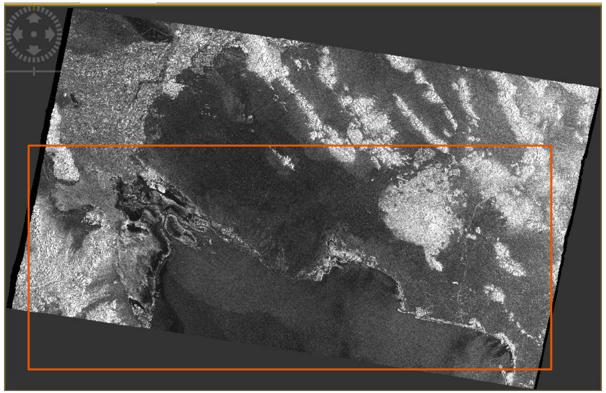
Gran Desierto de Altar - Sonora

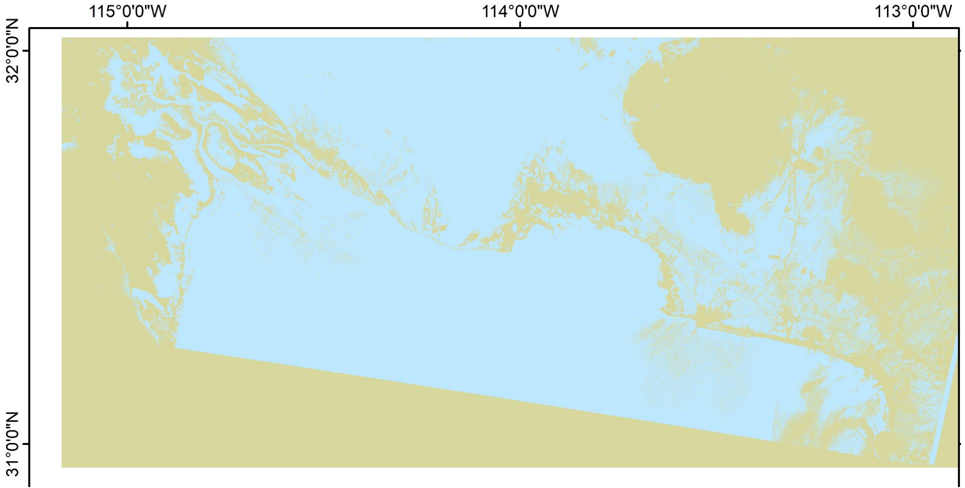
Sentinel-1
VH



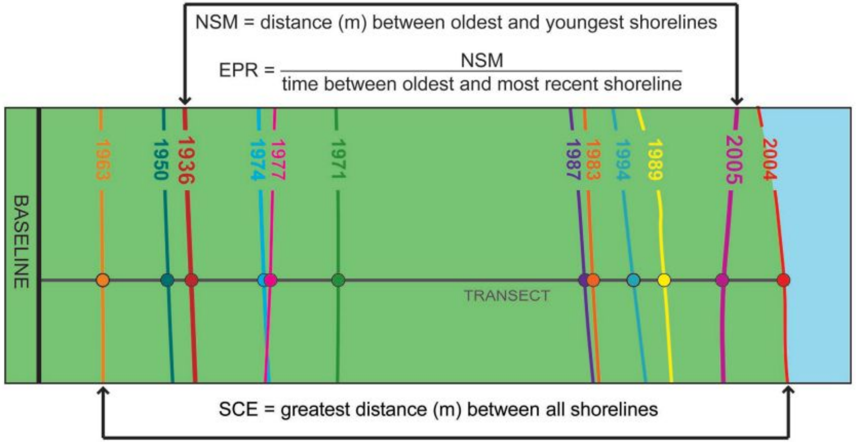


Sentinel-1
VV

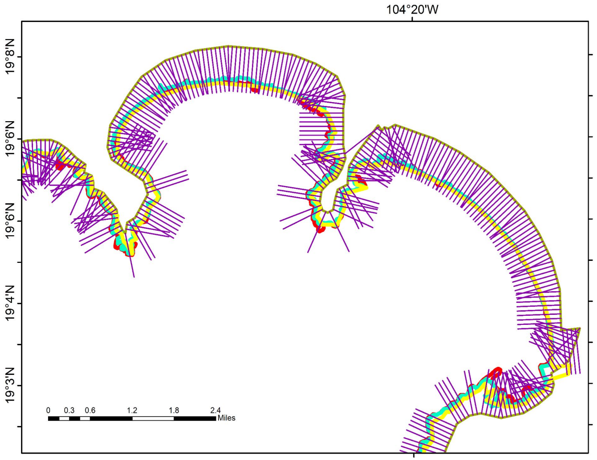


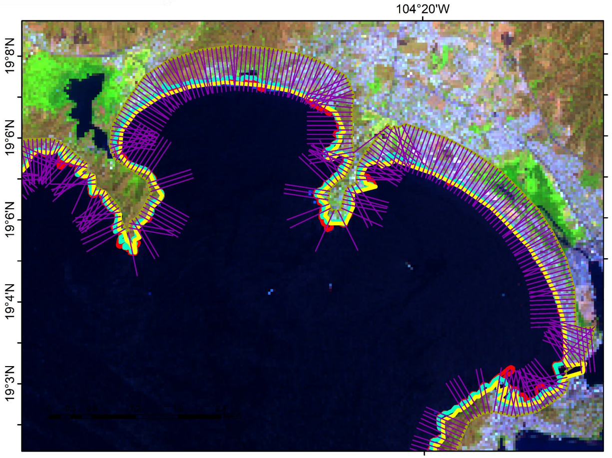


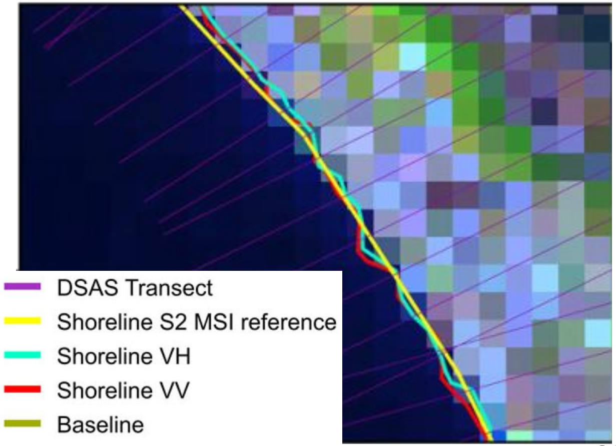
Himmelstoss, et al. (2018)



- Compute Digital Shoreline Analysis System (DSAS)
- Transects: Spacing=100m, length 500 m
- Comparison shoreline extraction of Sentinel-1 vs Sentinel-2







Analysis of the SAR shoreline using MCR

	Site A Isla Ángel de la Guarda, in the Gulf of California		Site B EL Vizcaíno Biosphere Reserve, in Baja California		Site C Chamela Bay, in Jalisco		Site D Manzanillo Bay and Santiago Bay, in Colima		Site E The port of La Pesca, in Tamaulipas		Site F Los Petenes Biosphere Reserve, in Campeche	
Polarization	VV	VH	VV	VH	VV	VH	VV	VH	VV	VH	VV	VH
Reference	S2A-MSI	S2A-MSI	S2B-MSI	S2B-MSI	S2B-MSI	S2A-MSI	S2B-MSI	S2B-MSI	S2A-MSI	S2A-MSI	S2A-MSI	S2A-MSI
Land-water mask Overall Acc. (%)	0.99	0.99	0.90	0.91	0.94	0.97	0.97	1.0	0.95	0.96	0.98	1.0
DSAS SCE mean (m)	46.53	39.21	59.29	86.42	71.43	67.20	127.65	103.33	38.04	39.49	50.94	43.25
DSAS RMSE mean	1.15	0.97	1.18	1.73	2.18	2.05	4.04	3.27	1.14	1.18	1.43	1.22
DSAS Bias	0.03	0.02	0.02	0.03	0.07	0.06	0.13	0.10	0.03	0.04	0.04	0.03
DSAS Total number of transects	1623		2510		1077		998		1115		1260	
DSAS Baseline length (m)	162,208.80		250,912.89		107,649.67		100,700.84		111,413.08		125,975.03	

Conclusions

- Under the studied conditions, it is possible to distinguish water/non-water areas which were successfully extracted.
- Frequent monitoring of the coastline is possible using Sentinel-1 over time.
- Digital shoreline map and database serve as a reference to the coastal manager.

Future work

- Identify the changes in the Mexican coast over time to support the territory management plans.

- Delineate water/non-water in coastal desert zones, where backscattering of sand affects the classification process.

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Thank you!

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https://www.tandfonline.com/doi/full/10.1080/10106049.2022.2109760

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