SAR IMAGERY OF THE MALDIVES

INTERNSHIP REPORT

BY

ASHWIN KUMAR

up202200273

MSIGOT

Supervisor: Professor Alberto Gomes, MSIGOT

CONTENTS

List of Figures

ACKNOWLEDGMENT

I would like to thank the supervisor of my internship, Professor Alberto Gomes, and Professor Stélio for guiding me to complete my internship project. I would also like to Thank CEGOT for accepting my internship project.

SUMMARY

For this internship report, we focus on the Digital Elevation Model (DEM) acquired using SAR (Synthetic Aperture Radar) imagery and generated using the Sentinel Application Platform (SNAP) with the help of ArcGIS. This data is obtained from Copernicus dataspace using the Sentinel 1 program in 2023 and is also compared with the DEM from NASA during 2014. We also try to understand the initial processes of Coral bleaching using Sentinel 2 data, using optical remote sensing imagery.

1 INTRODUCTION

1.1 Study Area of Maldives

Maldives is an archipelago located in the Indian Ocean, South Asia, south-southwest of India. It has a total land size of 298 km^2 which makes it the smallest country in Asia. It consists of 1190 coral islands forming 26 atolls spread across 90,000 km^2. The capital city of Maldives is Malé. Most of the atolls in Maldives consist of ring-shaped coral reefs that have many small islands. The temperature ranges between 24°C and 33 °C throughout the year with an annual rainfall of 2,540 mm. The tropical vegetation of Maldives differs in occupied and not occupied islands. Some of these islands have drumsticks, citrus and breadfruit trees. Along uninhabited islands, several types of mangroves are found along the waterline. Some of these islands are marshy. Most of the residents of these atolls depend on groundwater and rainwater.

Figure 1: Map of the Maldives

1.2 Objectives

- To generate a Digital Elevation Model (DEM) from Sentinel 1 Copernicus data.
- To analyze the DEM obtained from Sentinel 1 for 2023 for VV and VH polarization and USGS for 2014

1.3 SNAP software

The Sentinel Application Platform (SNAP) is an open – access Earth observation analysis tool which processes data from remote sensing Programs that include Sentinel 1, Sentinel 2 and Sentinel 3 from the European Union's Copernicus Program. It enables us to process and analyze remote sensing data for research education and training activities. SNAP was started in 2003 when the toolbox was named as BEAM which was utilized to view and process optical data from the agency's ERS and Envisat programs.

1.3.1 Sentinel 1

Sentinel 1 is a polar orbiting satellite that is part of the Copernicus Program conducted by the European Space Agency. It is optimized to provide Radar imagery for land and ocean regions during any weather including day and night. This program consists of 2 constellations of satellites 1A and 1B whereas 1C and 1D are still in development. It carries a Synthetic Aperture Radar instrument. This instrument has a spatial resolution of 5m and a swath of up to 410km. The first satellite Sentinel 1A was launched in 2014 and Sentel 1B was launched in 2016. The data obtained can be used for monitoring emergency responses due to environmental disasters and various economic applications. Users can acquire data for scientific or commercial purposes for free.

1.4 SAR Imagery

A method that improves the resolution of a radar image by using the motion of the radar platform to synthesize a larger antenna aperture (Massonnet et al 1998). Synthetic Aperture Radar or SAR uses the microwave region of the electromagnetic spectrum. It is a form of active remote sensing and therefore can be used in darkness and in different weather conditions. This type of imagery can be used to generate high resolution Digital Elevation Models to comprehend the geomorphology on the Surface of the Earth.

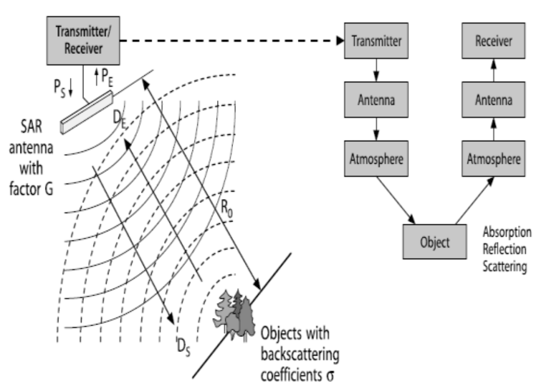


Figure 2: SAR imaging Process

1.5 History of CEGOT

The Centre of Studies in Geography and Spatial planning is a non-profit research and development unit that is divided into three research groups, Nature and environmental dynamics, cities and territorial development and Tourism, heritage, and territory. It is home to professors and researchers with backgrounds in Urban planning, Architecture, sociology, economics, and Tourism. Some of the main goals are to tackle climate change, demographic change, economic transitions, and social inequities. CEGOT celebrated its 10th year in 2018 and recognized by the Portuguese Foundation for Science and Technology in December 2008.

CEGOT
Centro de Estudos de Geografia
e Ordenamento do Território

1.6 References

The 2 main references that form the framework of this internship are

Buono et al. (2020), focused on utilizing SAR data to study the Goidhoo Atoll in the Maldvian Baa region. The goal was to understand the potential of this technology in monitoring atolls. ALOS PALSAR 2 SAR data was used which helped in identifying various coastline profiles and to classify different land and ocean features within the atoll.

Mcclanahan et al. (2007), conducted a project in East Africa from 1998 to 2005 on coral bleaching and mortality due to environmental stress. This project identifies distinct temperature environments on the coast predicting coral survival. It highlights distinct differences in how coral reefs respond to climate change.

Other references include

Ferretti et al (2001), present a problem with the potential of repeat-pass satellite SAR interferometry (InSAR) for DEM generation, by reviewing the limitations due to temporal and geometrical decorrelation and atmospheric disturbances. This research discusses the possible electromagnetic characteristics and dimensions of permanent scatterers for civil protection purposes and for using the ERS data set. The image shows DEM refinement, terrain motion detection for reliability on these permanent scatterers.

Quincey et al. (2006), discusses the use of remote sensing datasets to identify the hazardous lakes on the glaciers of the Himalayas using SAR imagery. They concluded that glaciers below 2 degrees have the most hazardous lakes. They generated a single interferogram from a pair of ERS-1/2 images. The study also identified that glaciers are vulnerable to lake development and outburst flood and suggested a predictive tool for hazard assessment based on surface gradient and velocity data.

Matgen et al. (2007) developed image processing methodologies that allowed the extraction of water levels from SAR imagery and combined them with precision data to generate flood depth maps. This proposal matched the requirements for real time flood management and pre flood and flood calibration and evaluation which could be possible due to the availability of these SAR images.

Dewan et al. (2007) studied the flood hazard in Dhaka, Bangladesh for the historical flood event of 1998 using SAR data. They found out that the greater portion of Dhaka comprised of moderate to very high hazard zones and just 8.04% was found to be the least vulnerable to potential flood hazards. Multi-date SAR imageries were used as hydrologic parameters.

Guzzetti et al. (2012) reviewed the principles for preparing landslide inventory maps with locations in an area. They use field surveys and aerial imagery based on LiDAR and SAR data. They found out that landslide inventory maps are important tools for documenting landslides but have limitations and uncertainties.

Betbeder et al. (2017), demonstrate the potential of SAR imagery on vegetation and landscape properties for connectivity modeling. Maps using SAR imagery improved landscape connectivity measures and explained 58% variance in carabid beetle abundance.

Putra et al. (2019), studied coral bleaching through sea surface temperature obtained from MODIS-Aqua and MODIS-Tera. The research focused on analyzing thermal stress via satellite data and field surveys. The research highlighted that coral bleaching was triggered mainly by temperature changes and solar intensity and indicated that recovery is possible but depends on temperature normalization and future anthropogenic influences. From the remote sensing data conducted from 2002 to 2017, this study concluded by advising safeguards that cloud coverage and turbid waters could mitigate the effects of solar radiation and temperature rise impacting coral reefs.

1.7 Internship Schedule

	Background Research	Data Acquisition and processing	SAR image Analysis	Data interpretation	Report Writing & Editing data
October	October 20 to October 25	October 26 to November 8			
November		November 9 to November 22	November 23 to November 30		
December				December 1 to December 8	December 9

2 METHODOLOGY

2.1 SAR IMAGERY

Prior to generating the DEM, there were a few processes that were followed. Two images have to be downloaded from Copernicus.

2.1.1 Data Selection

Two images were obtained from Copernicus.

Main image: 9th March 2023

Name of the image,

(S1A_IW_SLC__1SDV_20230520T005208_20230520T005240_048610_05D8B3_5D07)

Reference image: 5th May 2023

Name of the image,

(S1A_IW_SLC__1SDV_20230309T005205_20230309T005237_047560_05B60E_AB7D)

An already processed DEM is obtained from USGS for 2014.

2.1.2 Establishing a baseline

Once the data is downloaded from Copernicus open access data center, a baseline is to be found.

The Baseline Search provides visualization of perpendicular and temporal baseline data for a chosen reference scene. This information is obtained from the NASA Alaska satellite facility website. Data must be chosen from points above 150m to avoid errors.

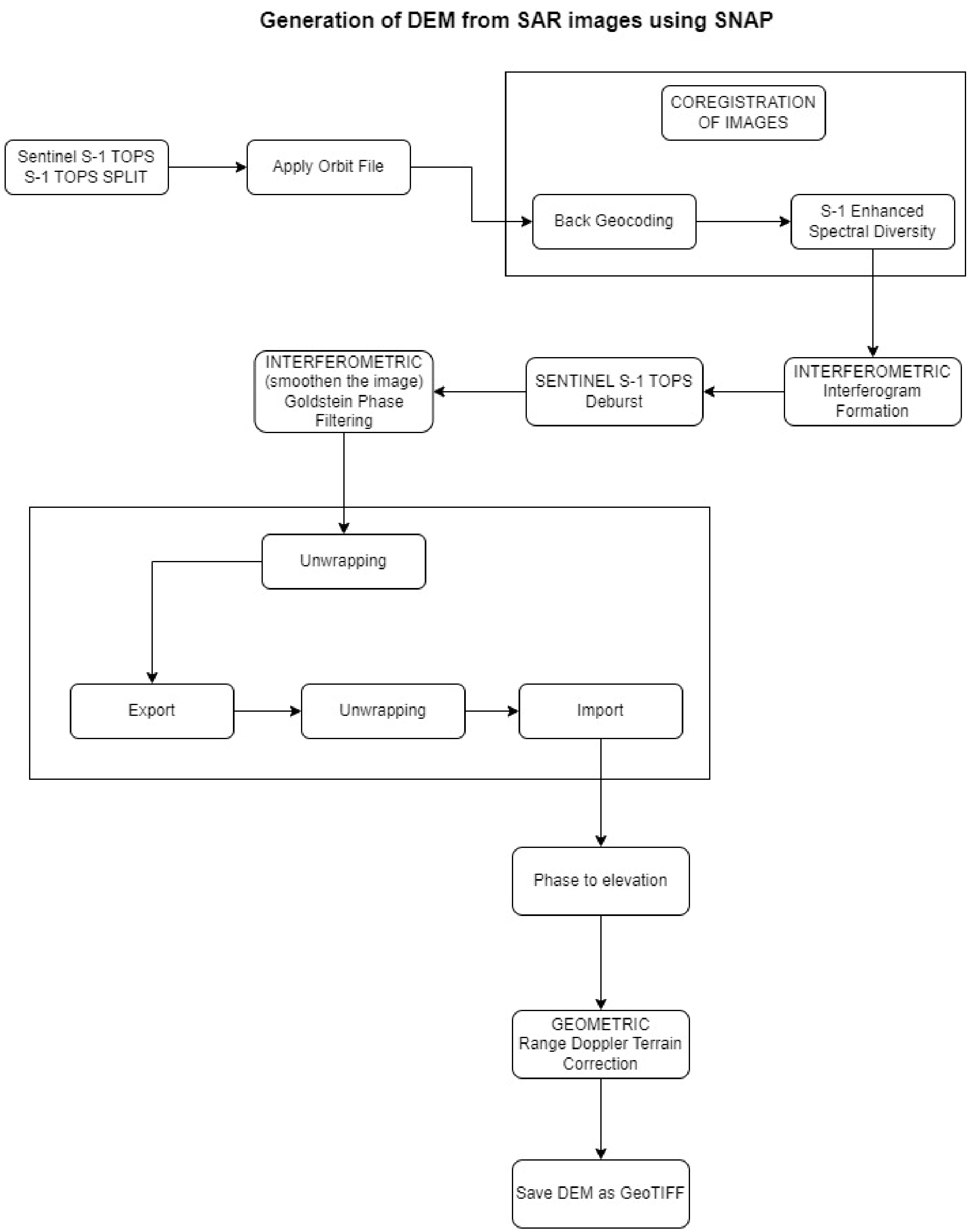
2.1.3 Downloading the other image

Once a baseline is established, the other image is downloaded in Copernicus. The images must be within the same year. In this case, the baseline selected data was 5th May 2023.

The 2 images are then added to the Sentinel Applications Platform (SNAP). This process is repeated twice for both VV and VH polarization of the images.

The main polarizations of land acquisitions are VV (Vertically transmitted and vertically received) and VH (Vertically transmitted and horizontally received). These types of polarization allow the separation of different scattering contributions and can be used to understand the information about the scattering process.

2.1.4 Process of Generation of the SAR image



The major steps of this procedure include the co-registration and Interferometric filtering of the images.

Co-registration: it is the process of aligning two or more images of the same area taken at separate times or by different sensors, SNAP allows the user to select the main image for study and then co-registers it with other images from the time series.

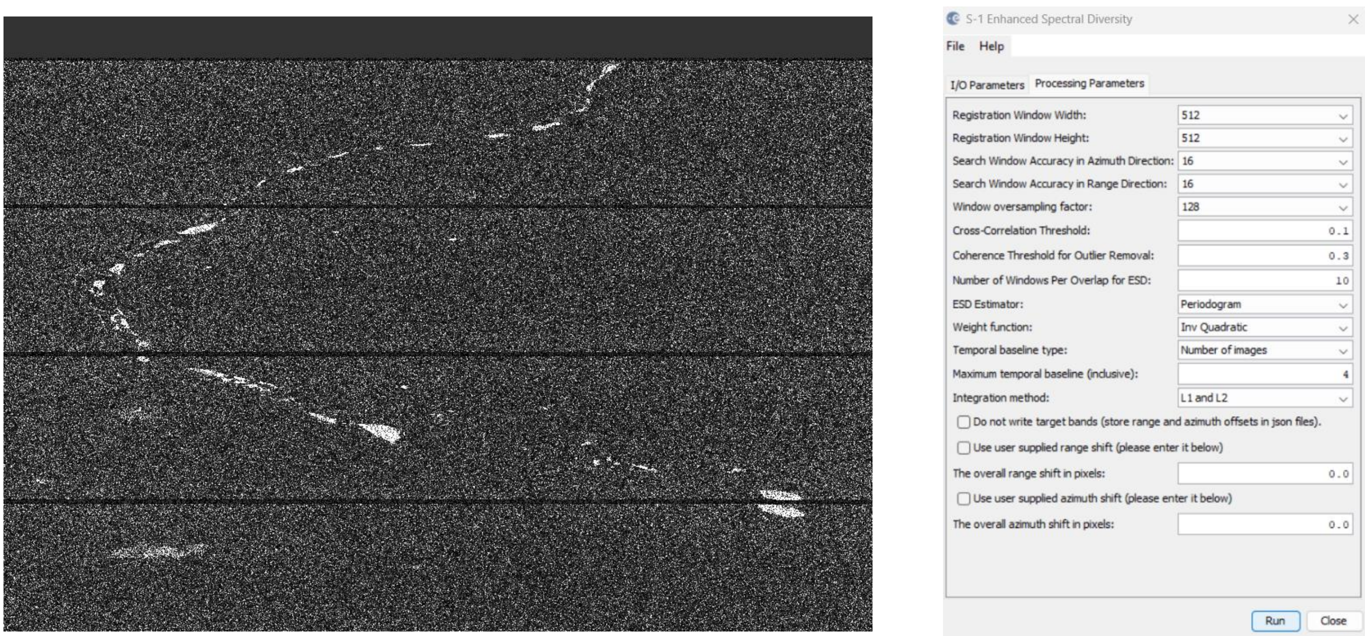


Figure 3: Co-registration of both images

Interferometry: it is a technique that uses the phase difference between 2 or more radar images of the same area to interpret information about the earth's surface.

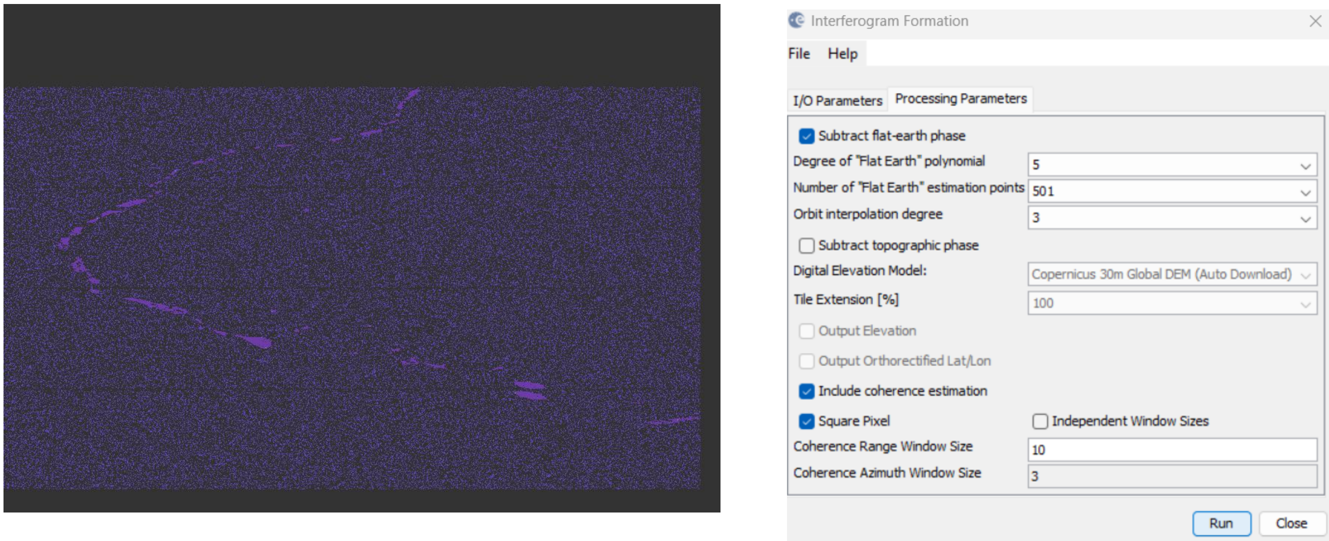
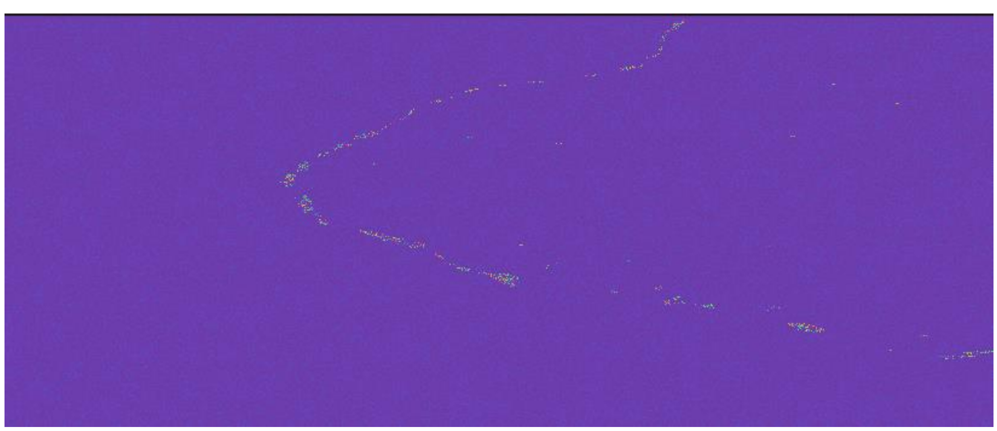


Figure 4: Interferometry

After the images are processed, they pass through the phase to elevation application where the points are generated and adjusted using the Geometric Range Doppler tool. The entire process takes 1 hour depending on the system.

The other steps in the program are less significant but are necessary to complete the above process.

Deburst: This procedure eliminates any lines created while combining the data as observed in the previous image.



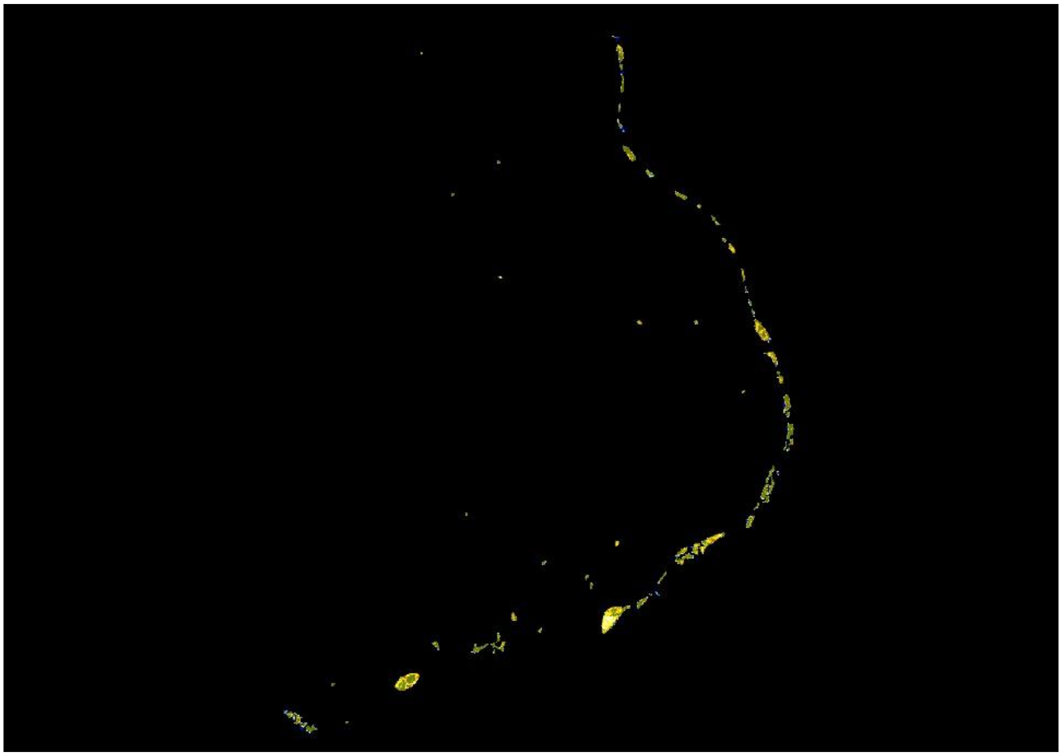


Figure 5: DEM Image generated by SNAP

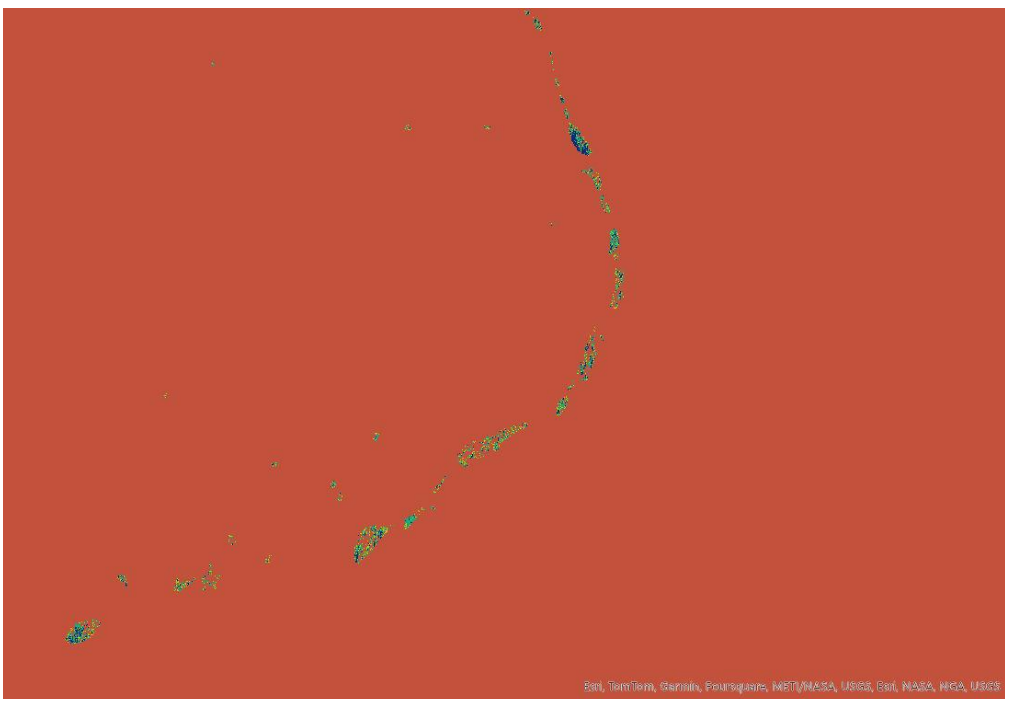
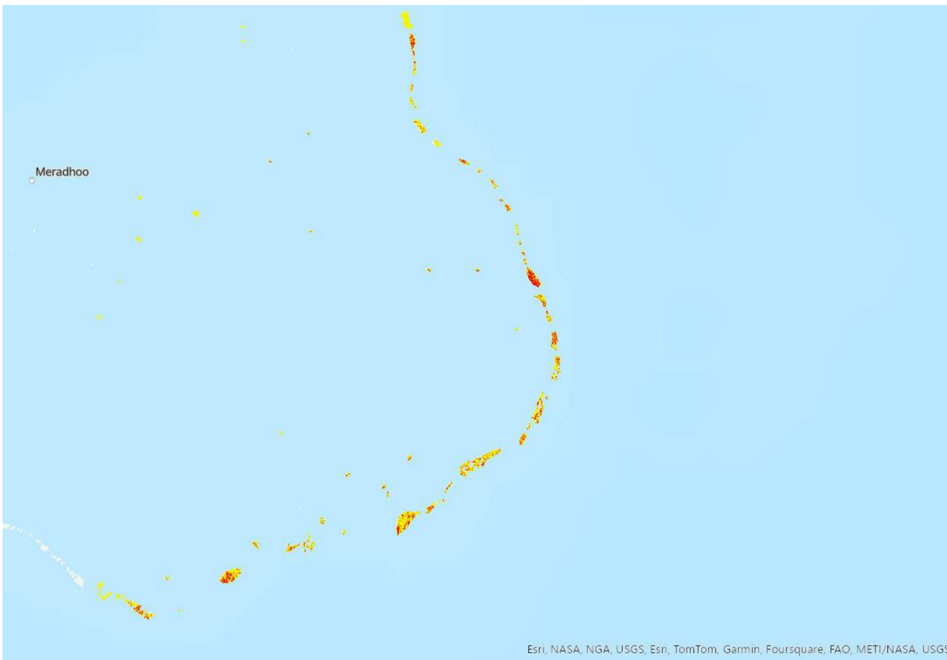


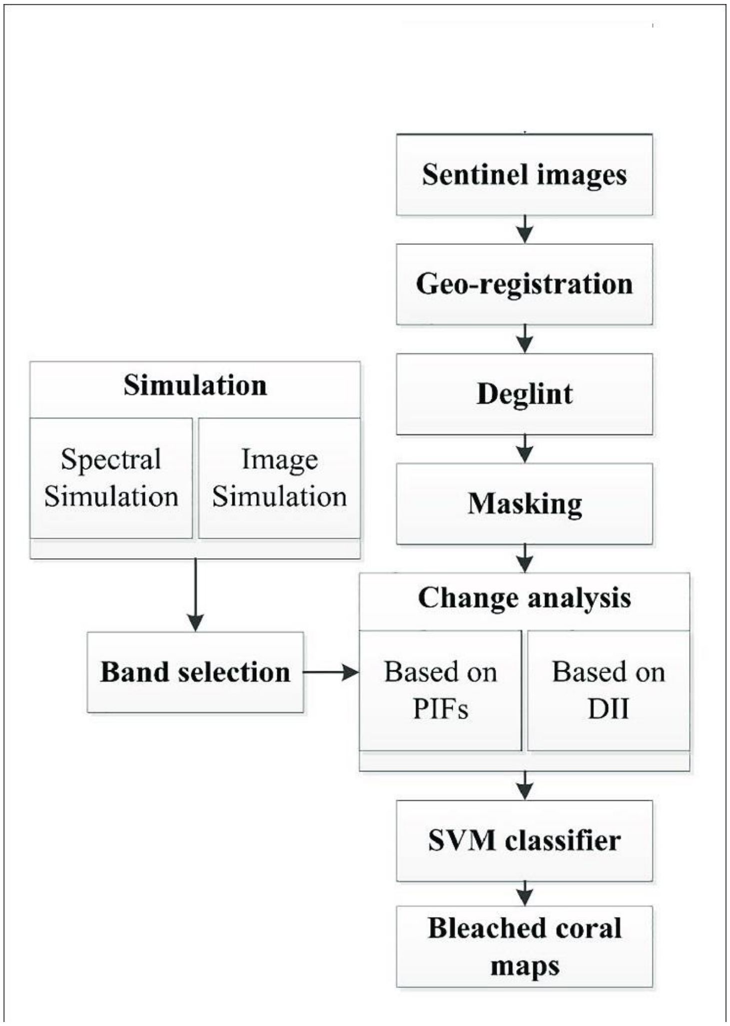
Figure 6: DEM Image transferred to ArcGIS

2.1.5 ArcGIS Processing

After processing the image, the DEM is then clipped with a shapefile of the Maldives. This image is then classified into different elevation points. A hill shade image is also generated by using the raster functions application within ArcGIS.



2.2 Sentinel 2 Imagery Process (Coral bleaching)



Coral bleaching describes a natural process where corals lose their color and turn white. This happens when corals are under stress due to an environmental disturbance. Coral bleaching is usually triggered by heat stress caused by increased water temperatures and UV radiation but can occur due to other factors such as changes in water quality. Using this process, we can determine the approximate number of disappearing coral reefs, the root cause and hypothetically implement changes that could prevent and possibly preserve these coral reefs.

3 RESULTS

The results of this internship will be based on the location in the Maldives of the 3 Atolls. We will evaluate the Digital Elevation Model of VV polarization, VH polarization from Sentinel 1 SAR imagery generated for 2023 and the USGS DEM imagery for 2014. Graphs shall be used for each Atoll to describe the variation in elevation of the atoll and differentiate between the polarizations and clarity of the image. We will also try to understand the hillshade patterns of these atolls and eventually draw conclusions based on these results.

3.1 Orthophotos of the study area

Figure 7: Google Satellite imagery of Atolls 1, 2 and 3

3.2 Study of Atoll 1

Figure 8: Study area for Atoll 1 (2023)

Figure 9: Study area for Atoll 1 (2014)

3.2.1 VV Polarization

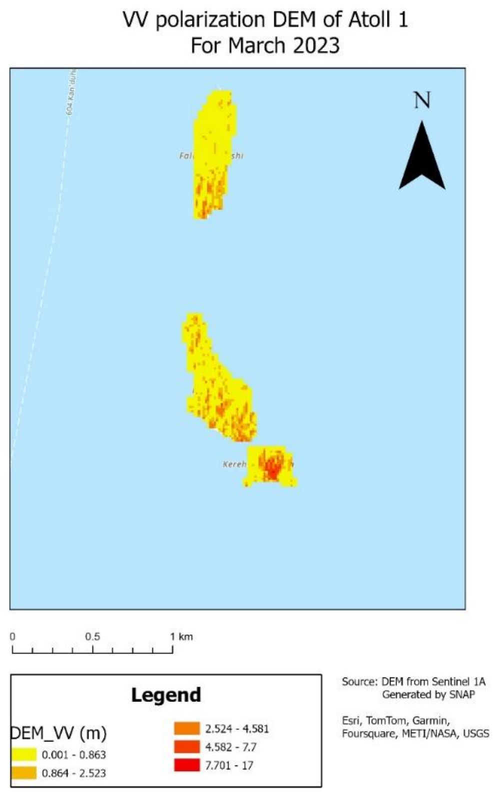


Figure 10: DEM (VV polarization) for Atoll 1 (2023)

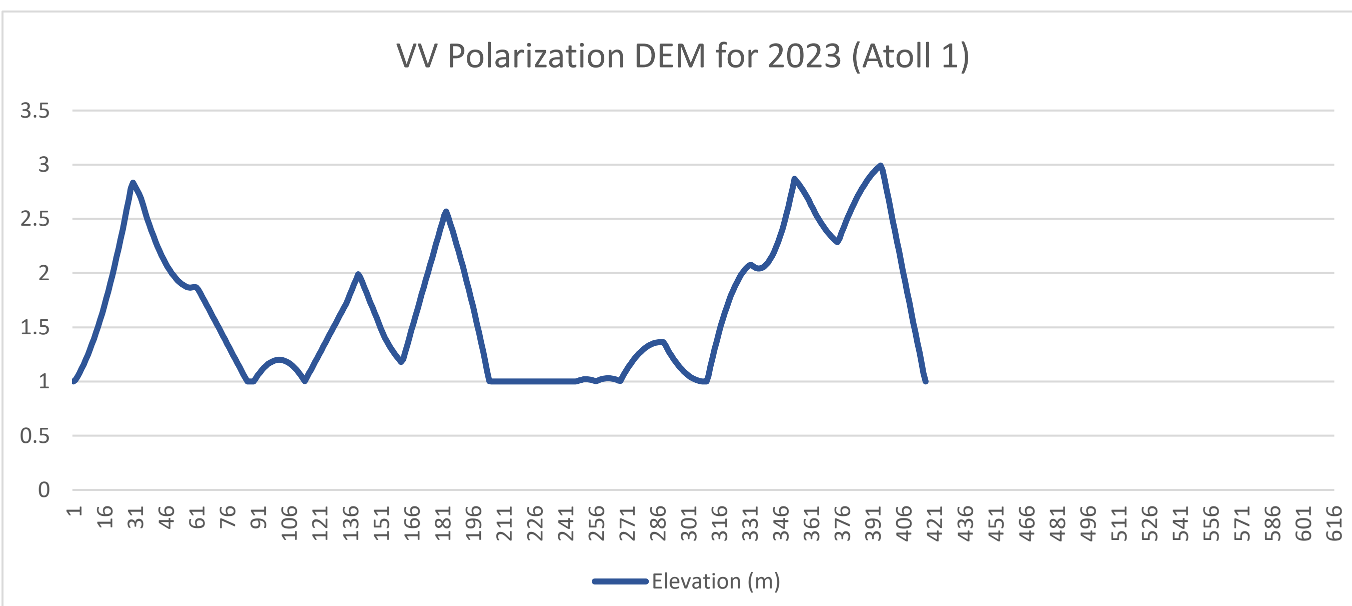


Figure 11: Graph distribution of DEM points (VV polarization) for Atoll 1 (2023)

3.2.2 VH Polarization

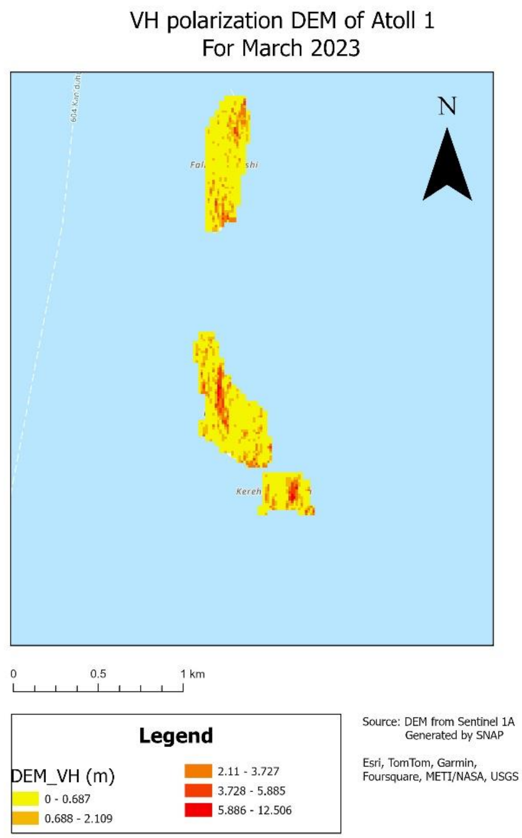


Figure 12: DEM (VH polarization) for Atoll 1 (2023)

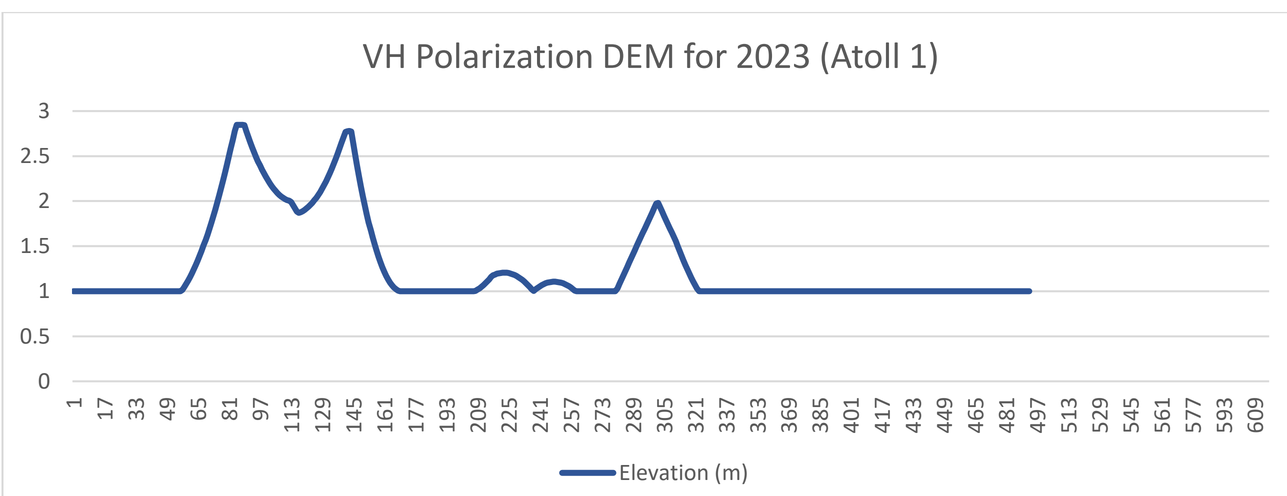


Figure 13: Graph distribution of DEM points (VH polarization) for Atoll 1 (2023)

3.2.3 USGS DEM

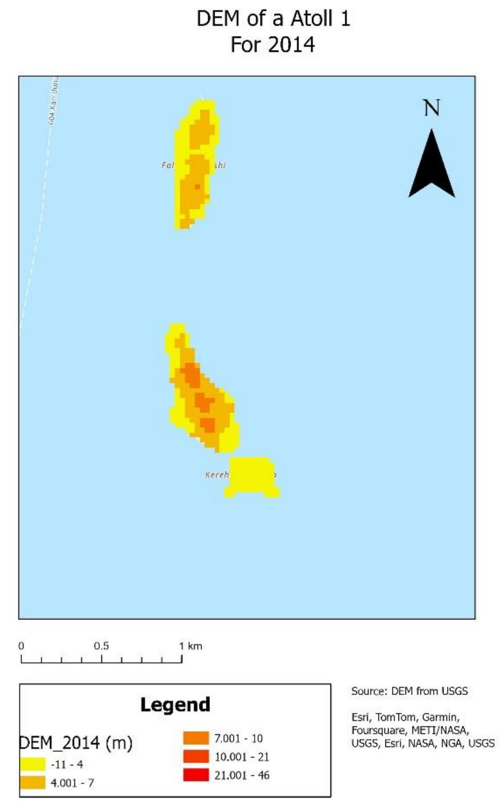


Figure 14: DEM (USGS) for Atoll 1 (2014)

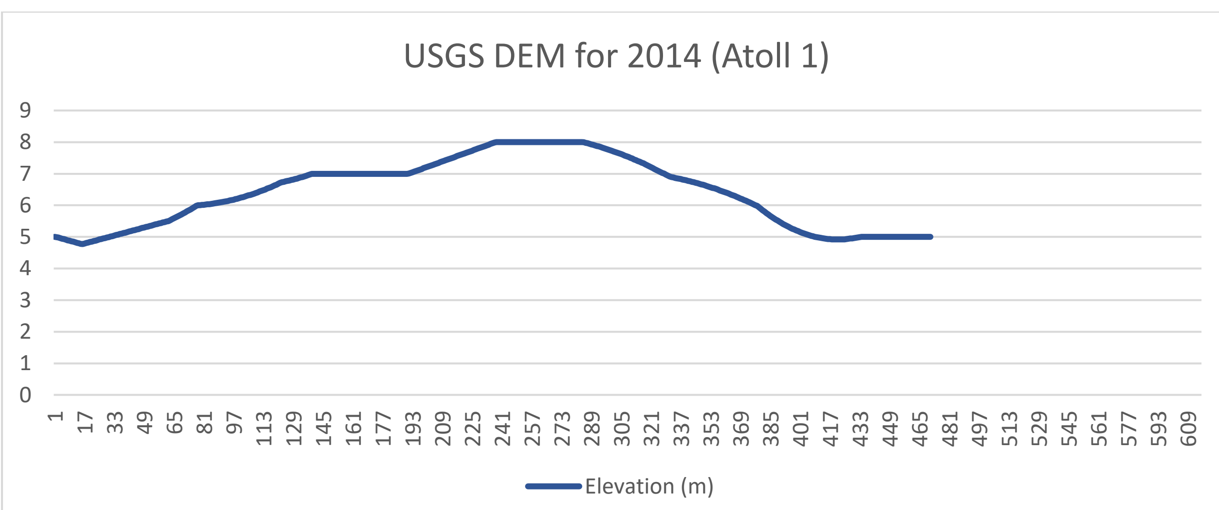


Figure 15: Graph distribution of DEM points (USGS) for Atoll 1 (2014)

From this map, we can determine the variation in the values. With the help of the graph below, we know that the highest value is at distance point 394 at 2.95431m for a selected area. Even with the absence of a DEM, we can see a significant difference between images 2014 and 2023 in urban development and terrain changes. We notice the variance at the center of the island and the offshore construction.

For Atoll 1, the VV polarization has a higher mean elevation than the VH polarization image as indicated by the elevation profile in the graph. VV polarization shows a greater number of DEM points above 2 meters while the VH polarization shows that it has DEM points below 2 meters. In this case, the VV Polarization has a higher clarity to surface roughness than VH polarization as well as showing more variation and oscillations in the elevation values while VH polarization shows more consistent values. The DEM from USGS shows a more generalized distribution of points with the mean height being 3m.

3.3 Study of Atoll 2

Figure 16: Study area for Atoll 2 (2023)

Figure 17: Study area for Atoll 2 (2014)

3.3.1 VV Polarization

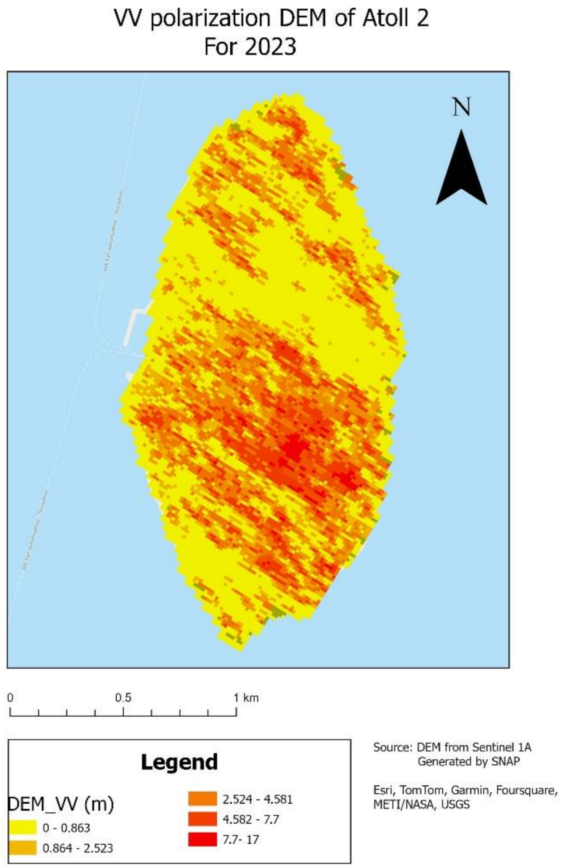


Figure 18: DEM (VV polarization) for Atoll 2 (2023)

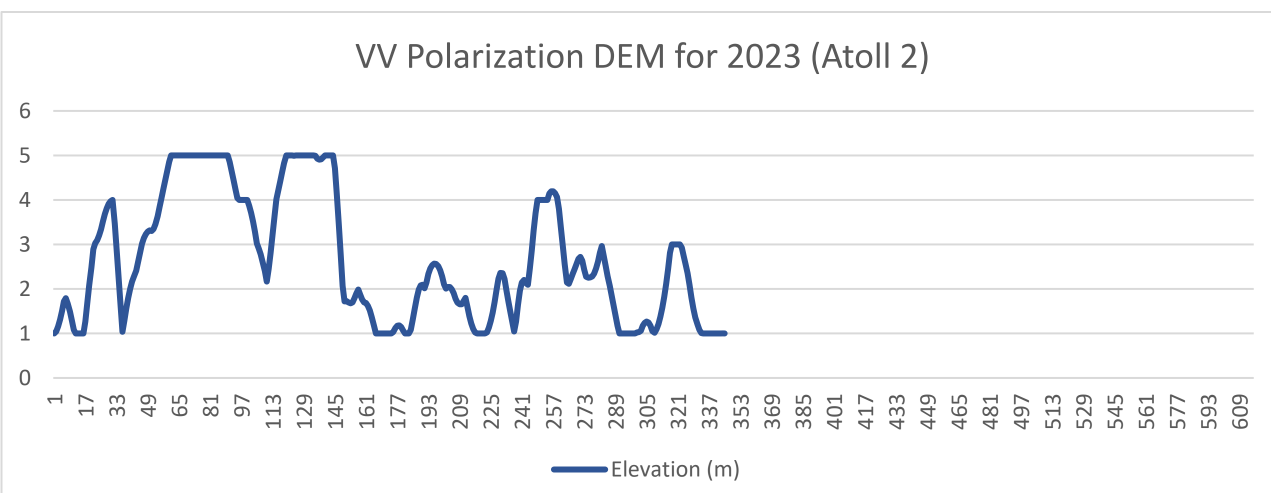


Figure 19: Graph distribution of DEM points (VV polarization) for Atoll 2 (2023)

3.3.2 VH Polarization

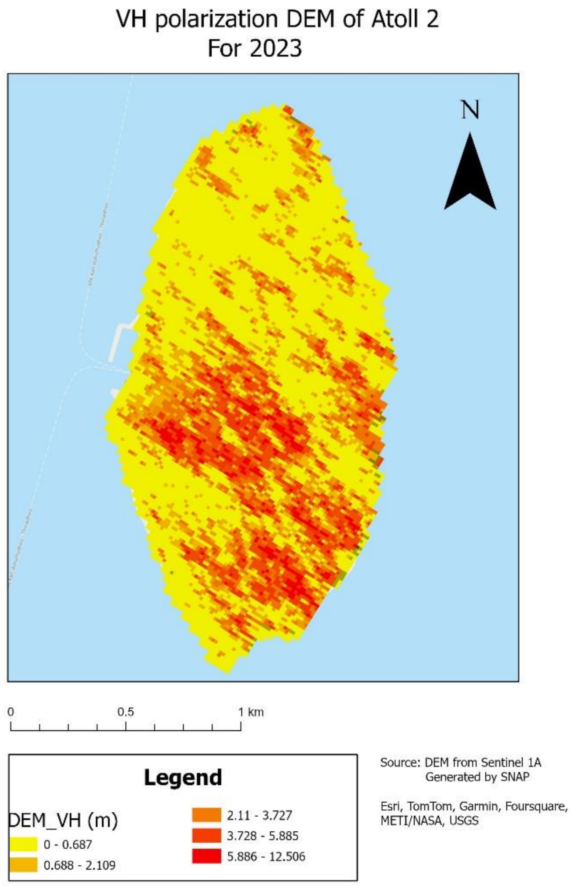


Figure 20: DEM (VH polarization) for Atoll 2 (2023)

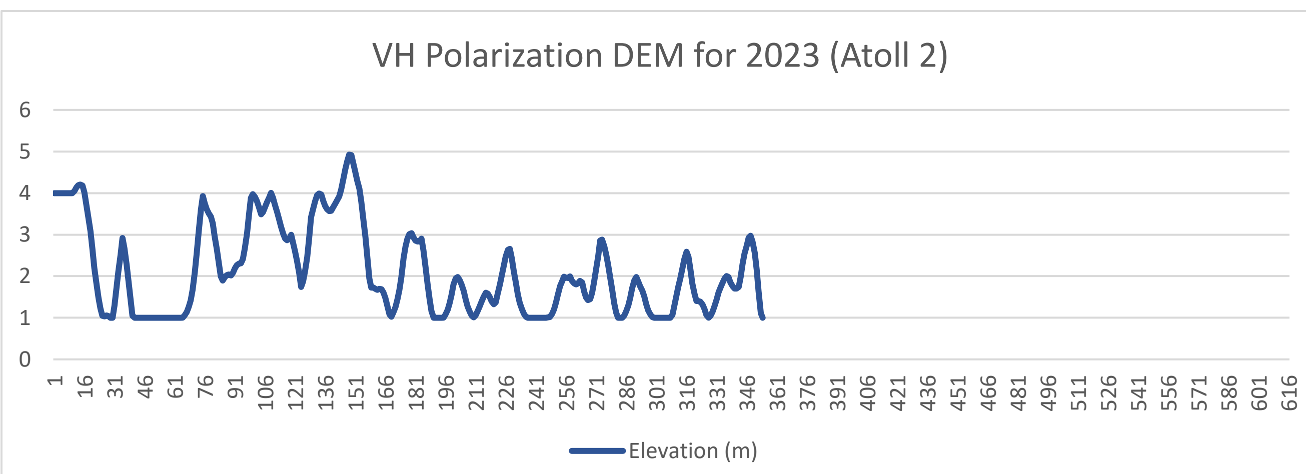


Figure 21: Graph distribution of DEM points (VH polarization) for Atoll 2 (2023)

3.3.3 USGS DEM

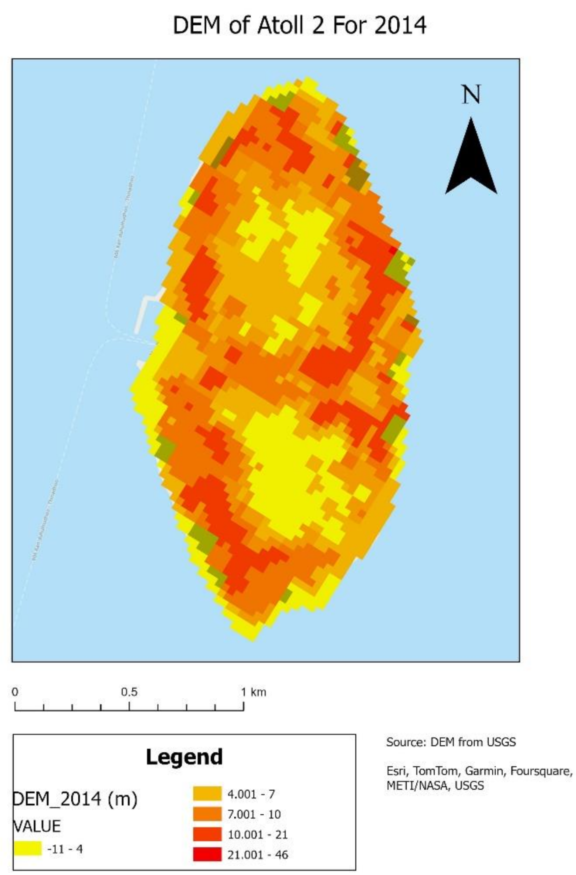


Figure 22: DEM (USGS) for Atoll 2 (2014)

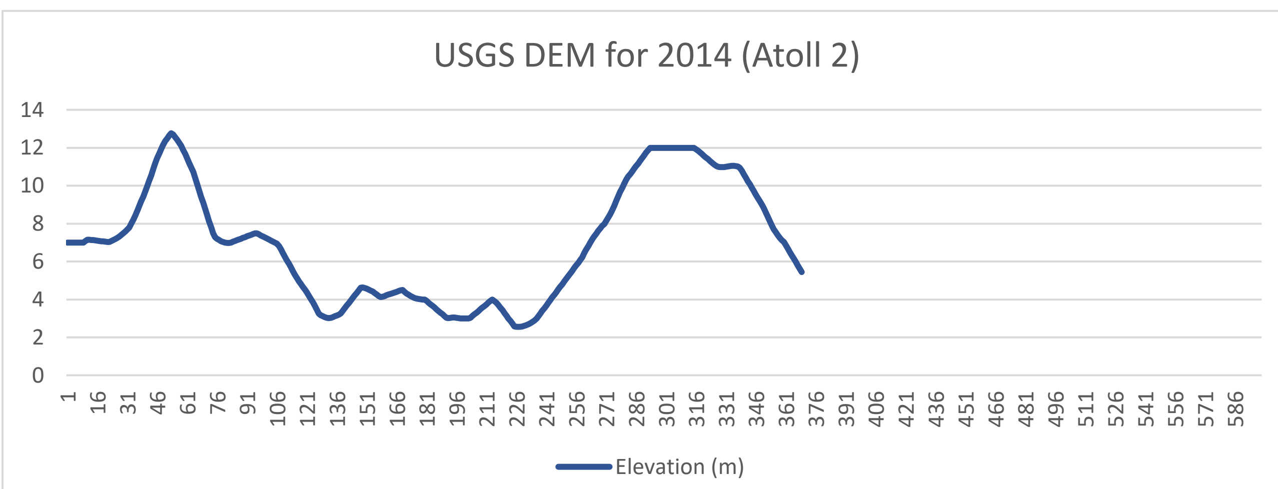


Figure 23: Graph distribution of DEM points (USGS) for Atoll 2 (2014)

In the case of Atoll 2, the VH polarization shows more variation in elevation values than VV polarization. The distribution of DEM points from VH polarizations shows a dispersed pattern as compared to the VV polarization indicating that there is an interference with the water surface and the radar signal. The elevation values show a difference from 0 to 6 meters for VV polarization whereas the range of elevation values range from 0 to 4 meters for VH polarization. VV polarization is more sensitive to the surface roughness and vegetation of the atoll while VH polarization is influenced by the water surface and the surrounding features. The USGS DEM is like the VH polarization DEM graph but is completely different from the VV polarization graph.

The USGS DEM for 2014 shows values ranging from 0 to 14 meters which implies that within 9 years, the atoll could have undergone erosion or changes in sea level as there is not much difference in the urban development of this region as observed in the satellite images.

3.4 Study of Atoll 3

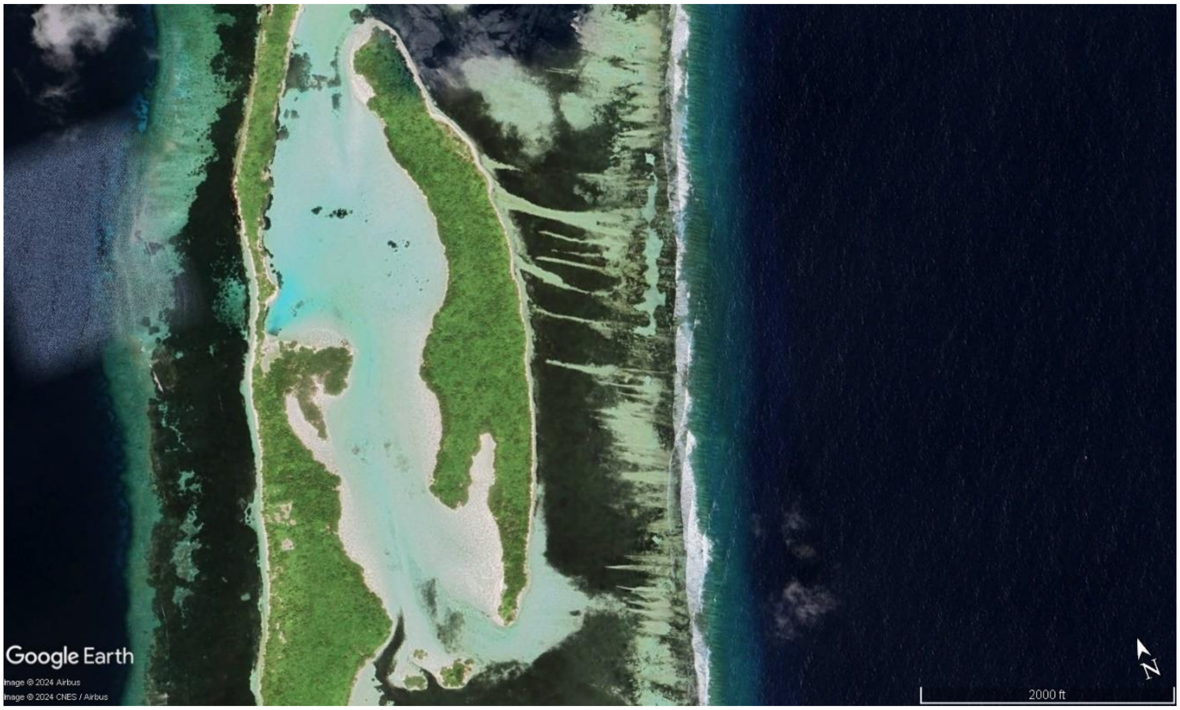


Figure 24: Study area for Atoll 3 (2023)

Figure 25: Study area for Atoll 3 (2014)

3.4.1 VV Polarization

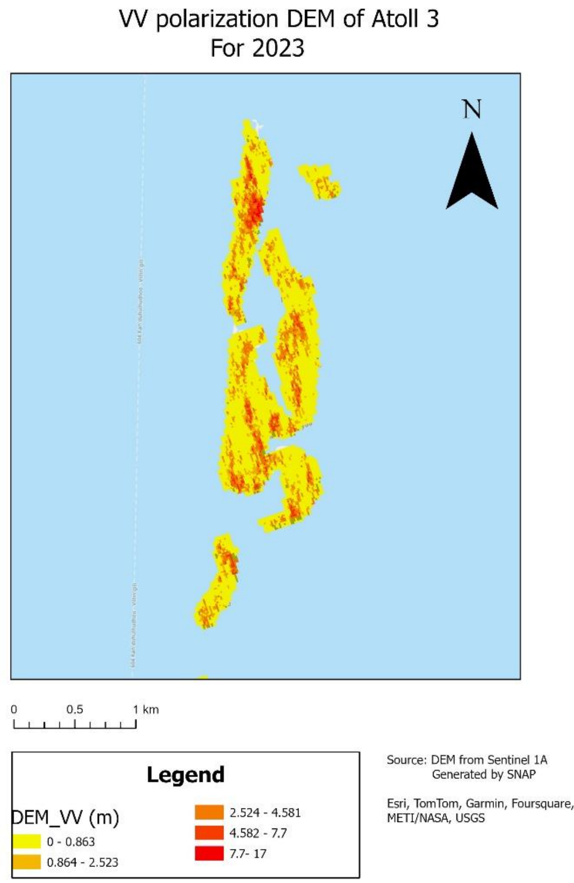


Figure 26: DEM (VV polarization) for Atoll 3 (2023)

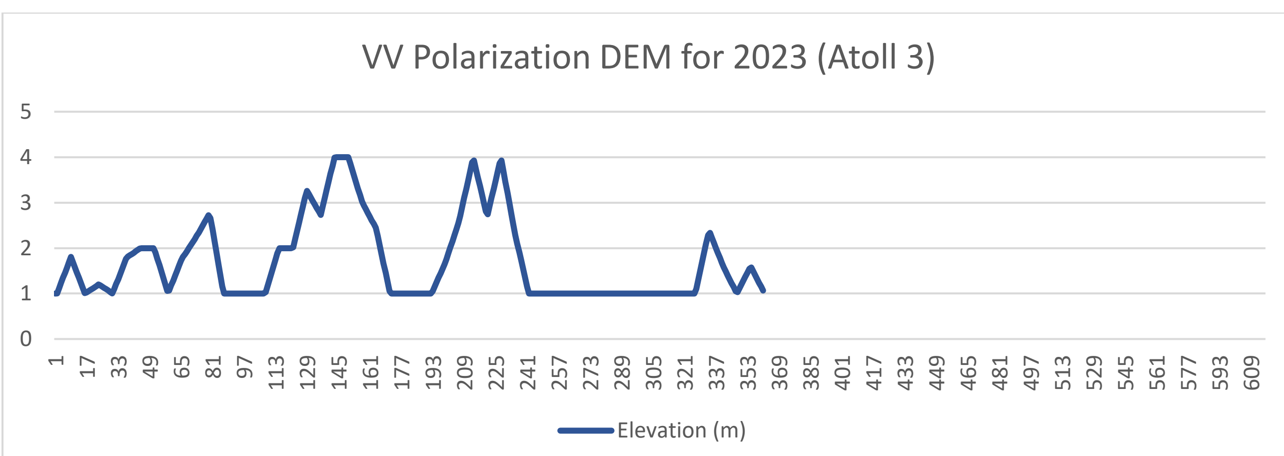


Figure 27: Graph distribution of DEM points (VV polarization) for Atoll 3 (2023)

3.4.2 VH Polarization

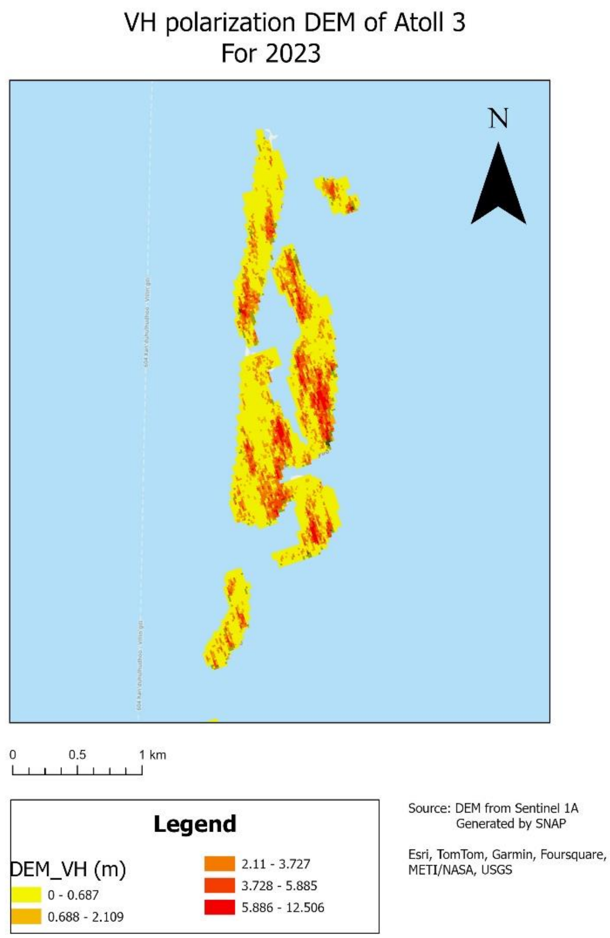


Figure 28: DEM (VH polarization) for Atoll 3 (2023)

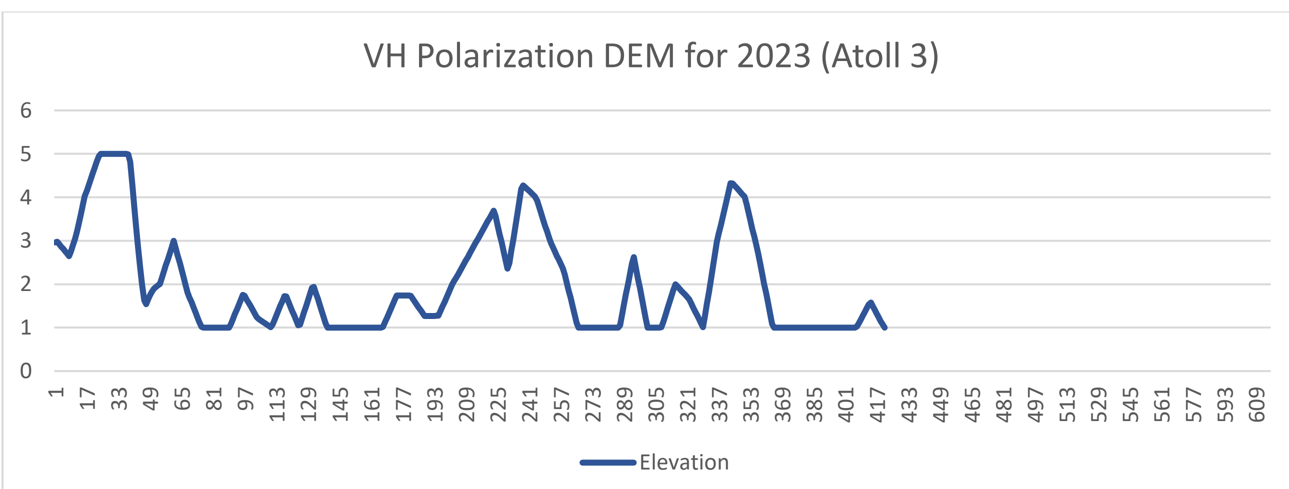


Figure 29: Graph distribution of DEM points (VH polarization) for Atoll 3 (2023)

3.4.3 USGS DEM

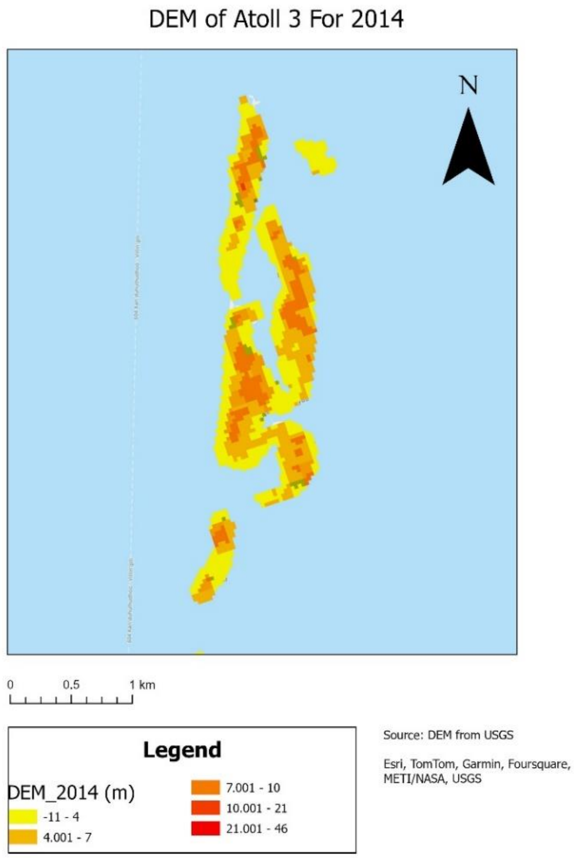


Figure 30: DEM (USGS) for Atoll 3 (2014)

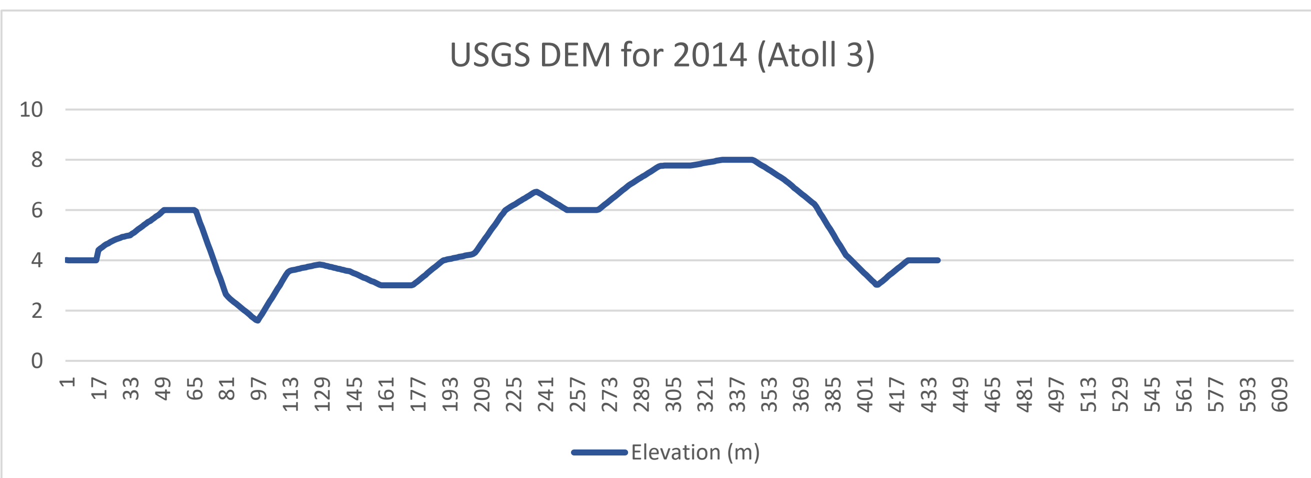


Figure 31: Graph distribution of DEM points (USGS) for Atoll 2 (2014)

For Atoll 3, the VV polarization indicates 2 dominant elevation levels at 2m and 4m whereas the VH polarization DEM shows just one dominant elevation level that corresponds to the elevation of the land. The mean elevation is almost 2.5m and shows more points clustered around the mean elevation. For the USGS DEM image, the points are evenly distributed across the elevation range. In this case, the USGS DEM has a higher and more varied elevation range than the rest of the polarization images. From the satellite images, we can observe that there has not been much change in the area as proven by the even elevation profiles for both the years.

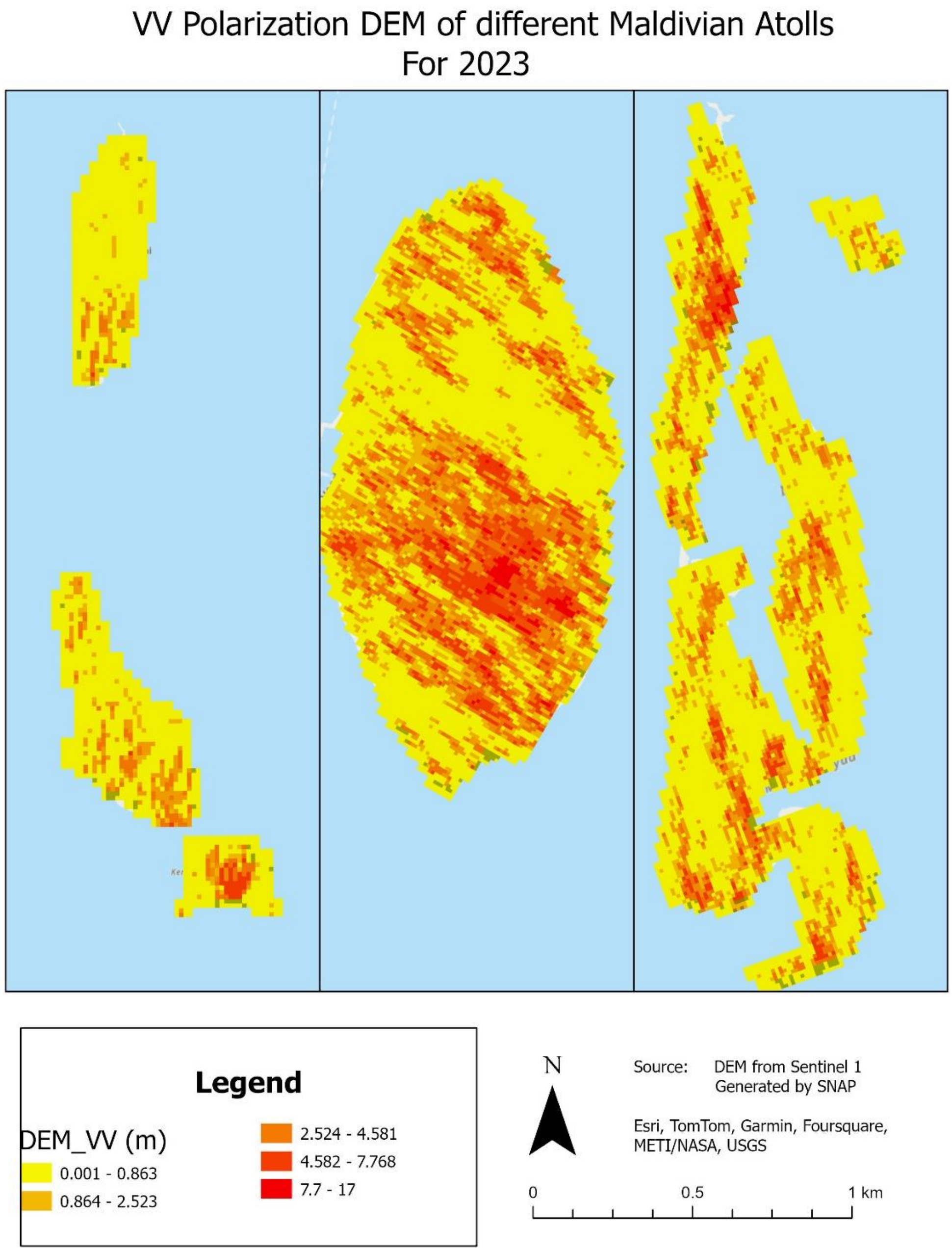


Figure 32: DEM (VV Polarization) by SAR imagery of all Atolls for 2023

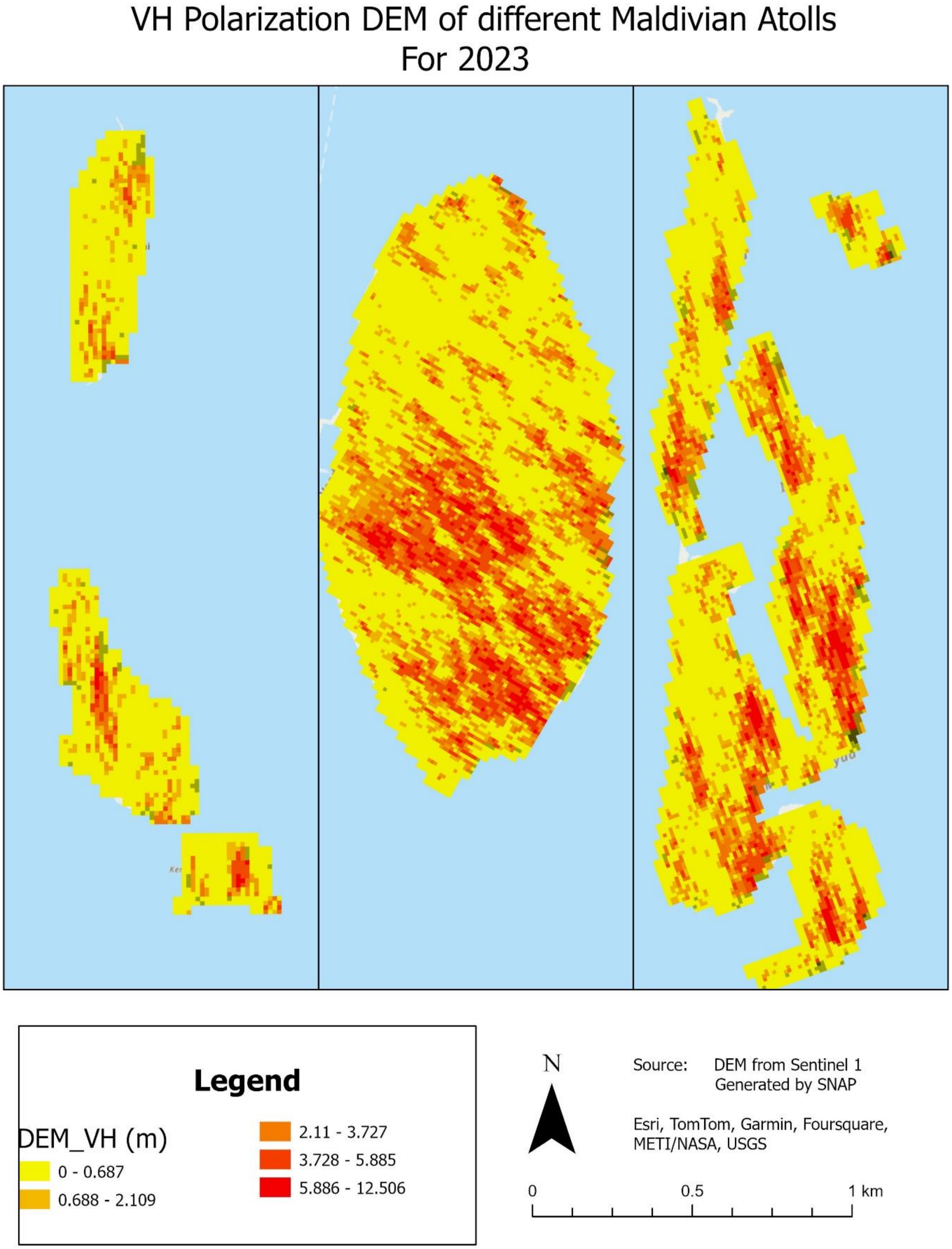


Figure 33: DEM (VH Polarization) by SAR imagery of all Atolls for 2023

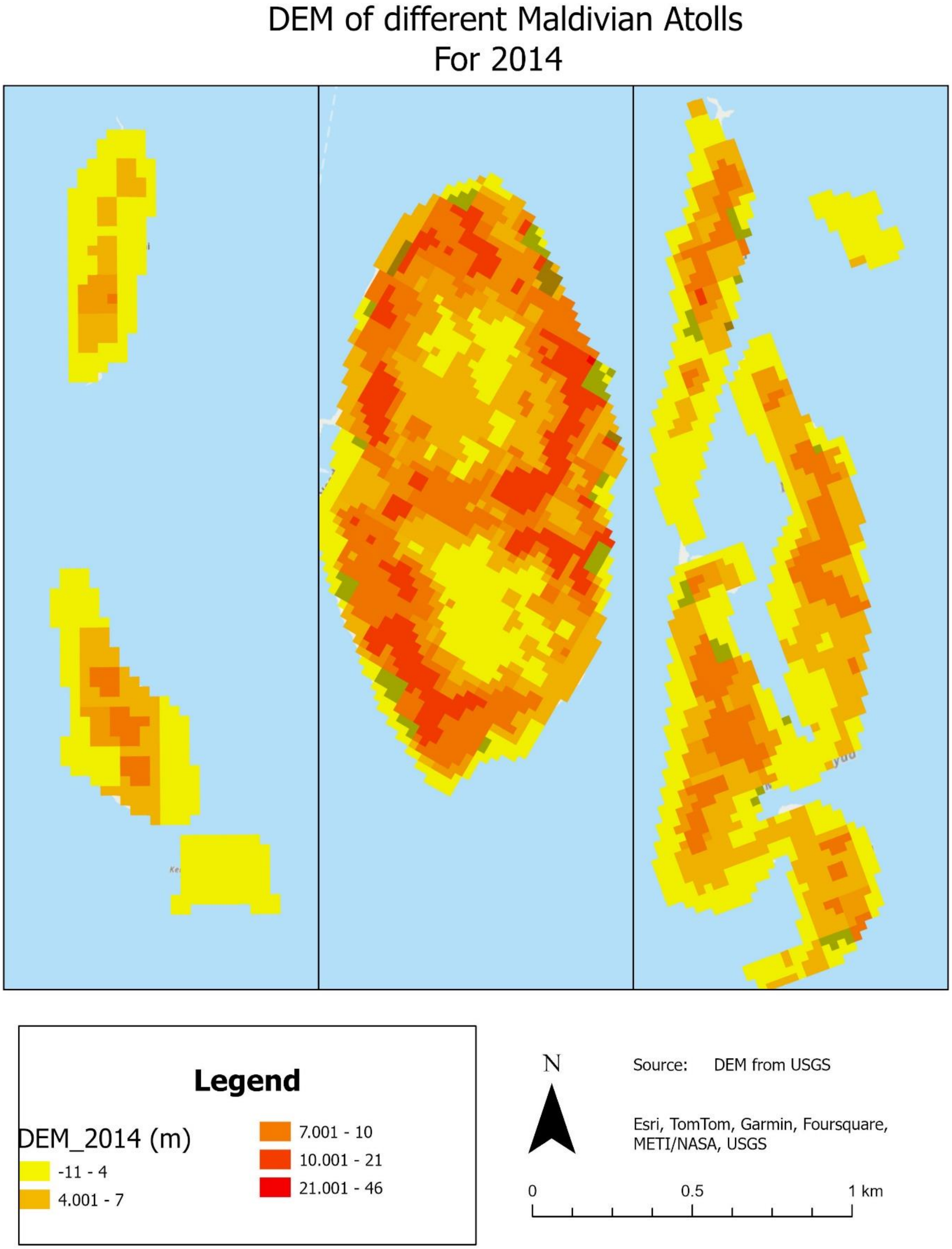


Figure 34: DEM (USGS) imagery of all Atolls for 2014

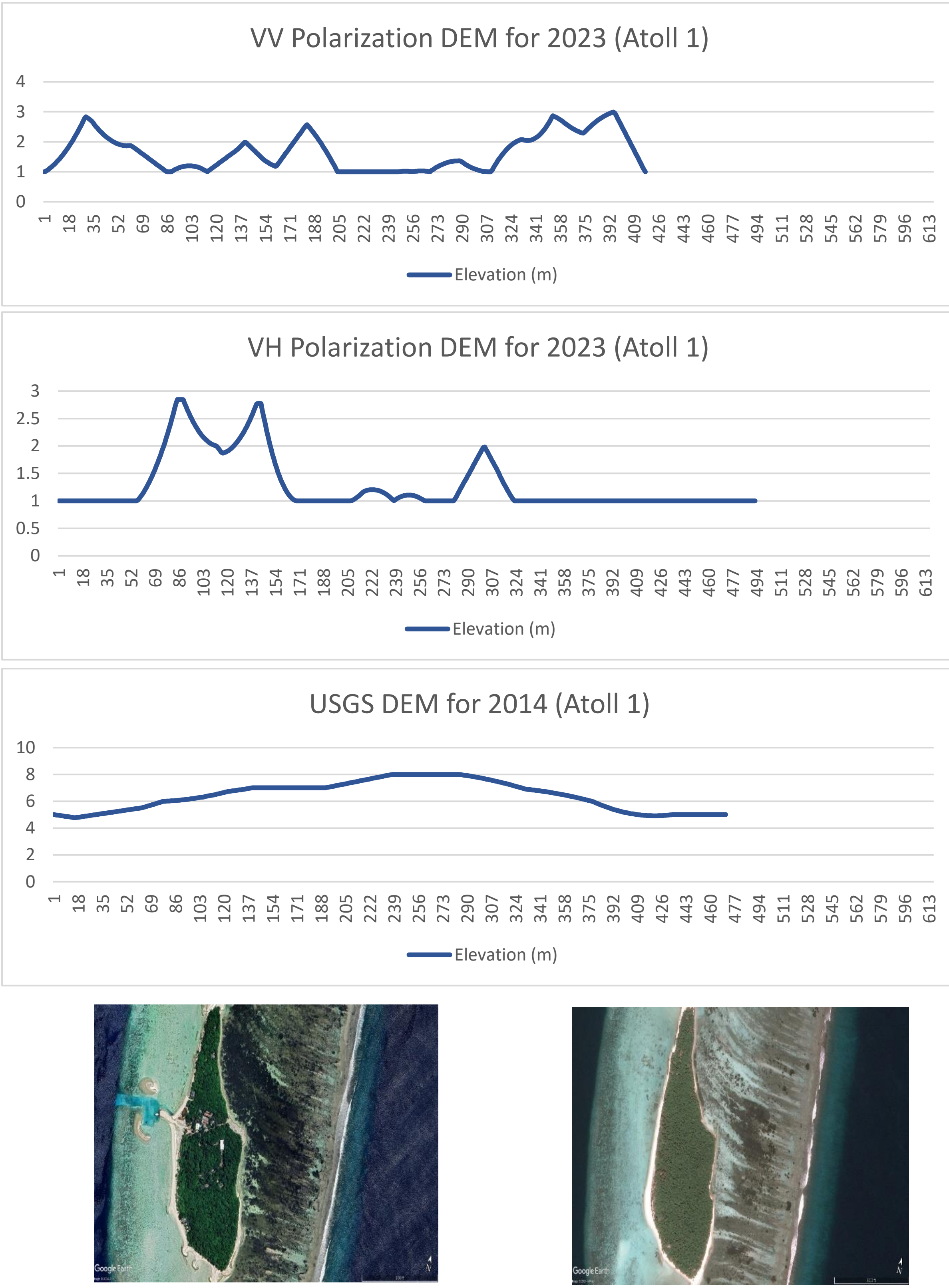


Figure 35: Graphs with all DEMS of Atoll 1 along with satellite imagery of 2023 and 2014

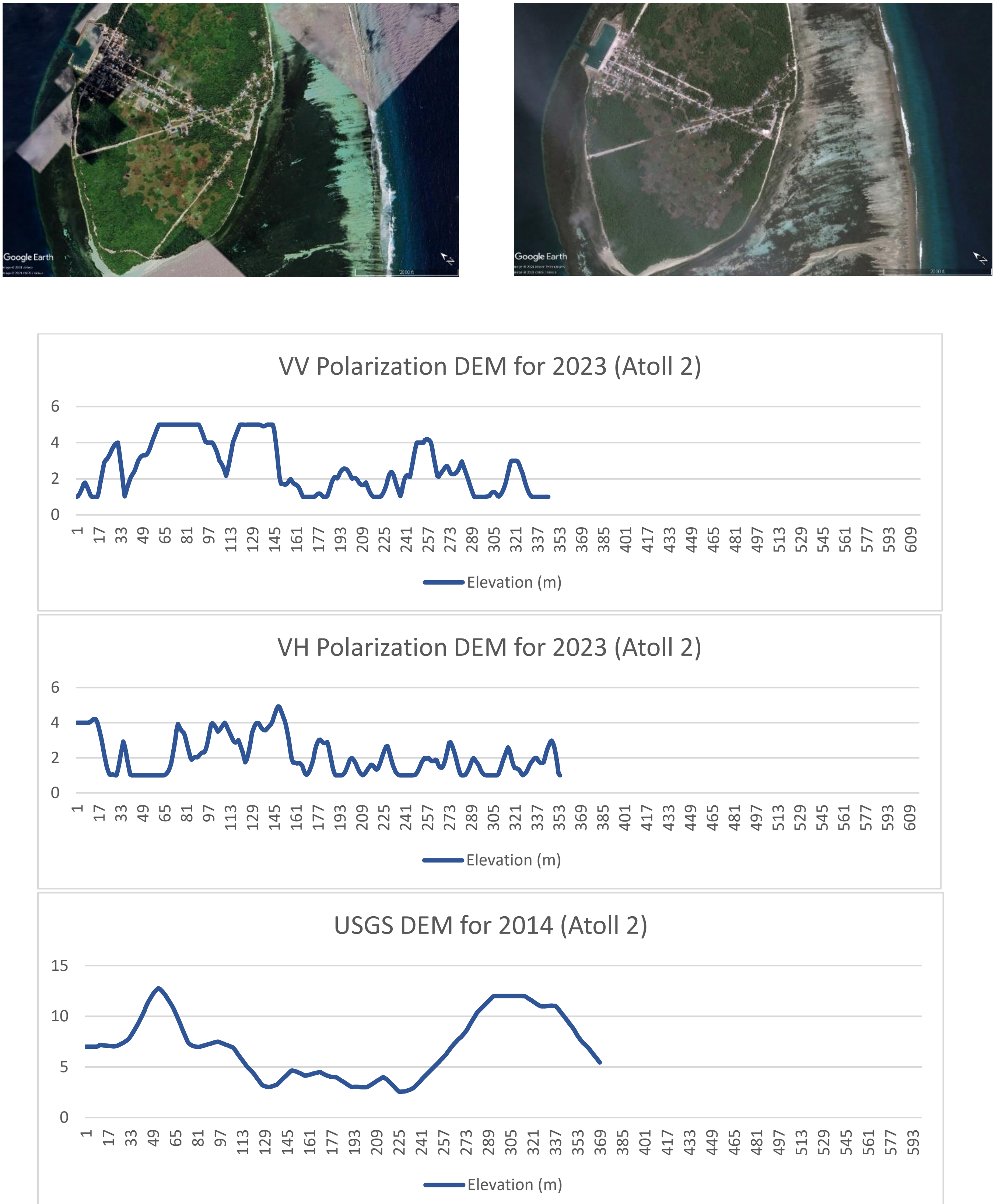


Figure 36: Graphs with all DEMS of Atoll 2 along with satellite imagery of 2023 and 2014

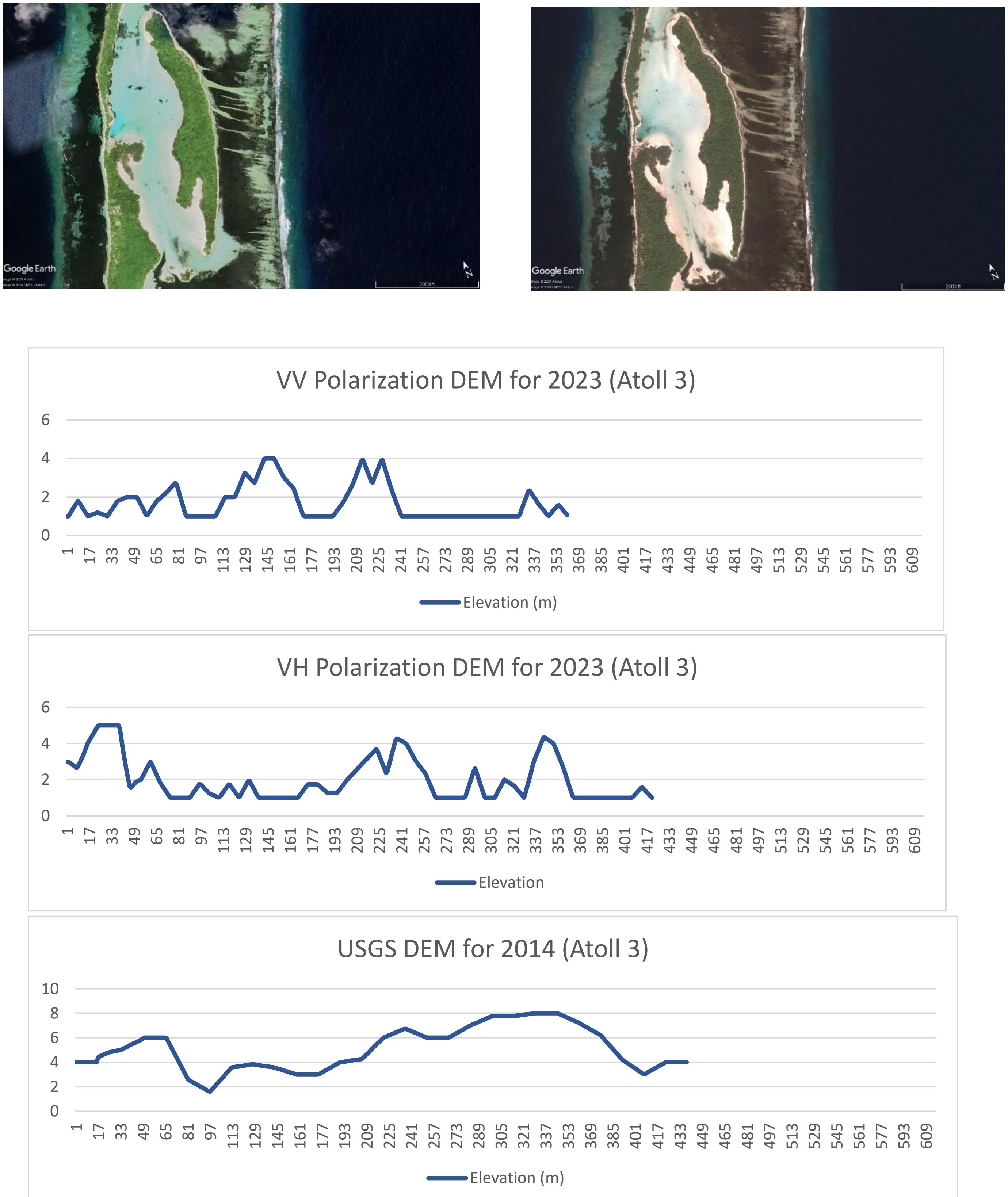


Figure 37: Graphs with all DEMS of Atoll 3 along with satellite imagery of 2023 and 2014

3.5 Hillshade imagery of the Atolls

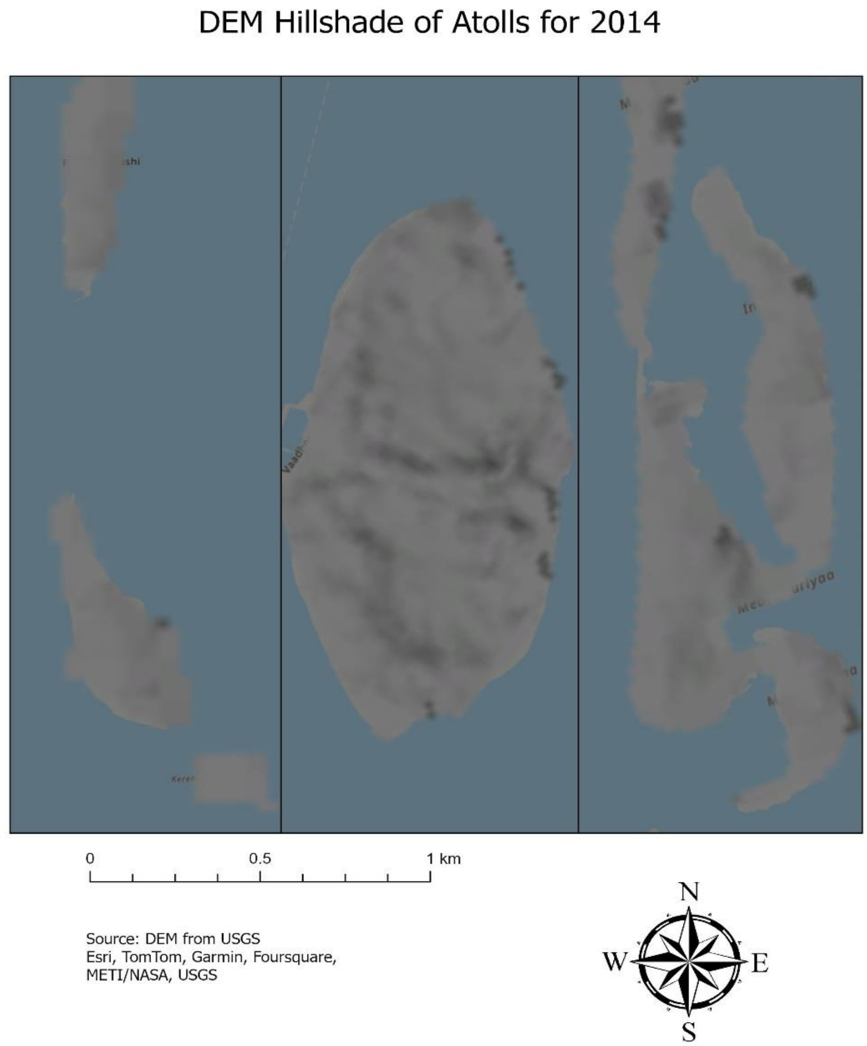


Figure 38: HillShade (USGS) for the atolls (2014)

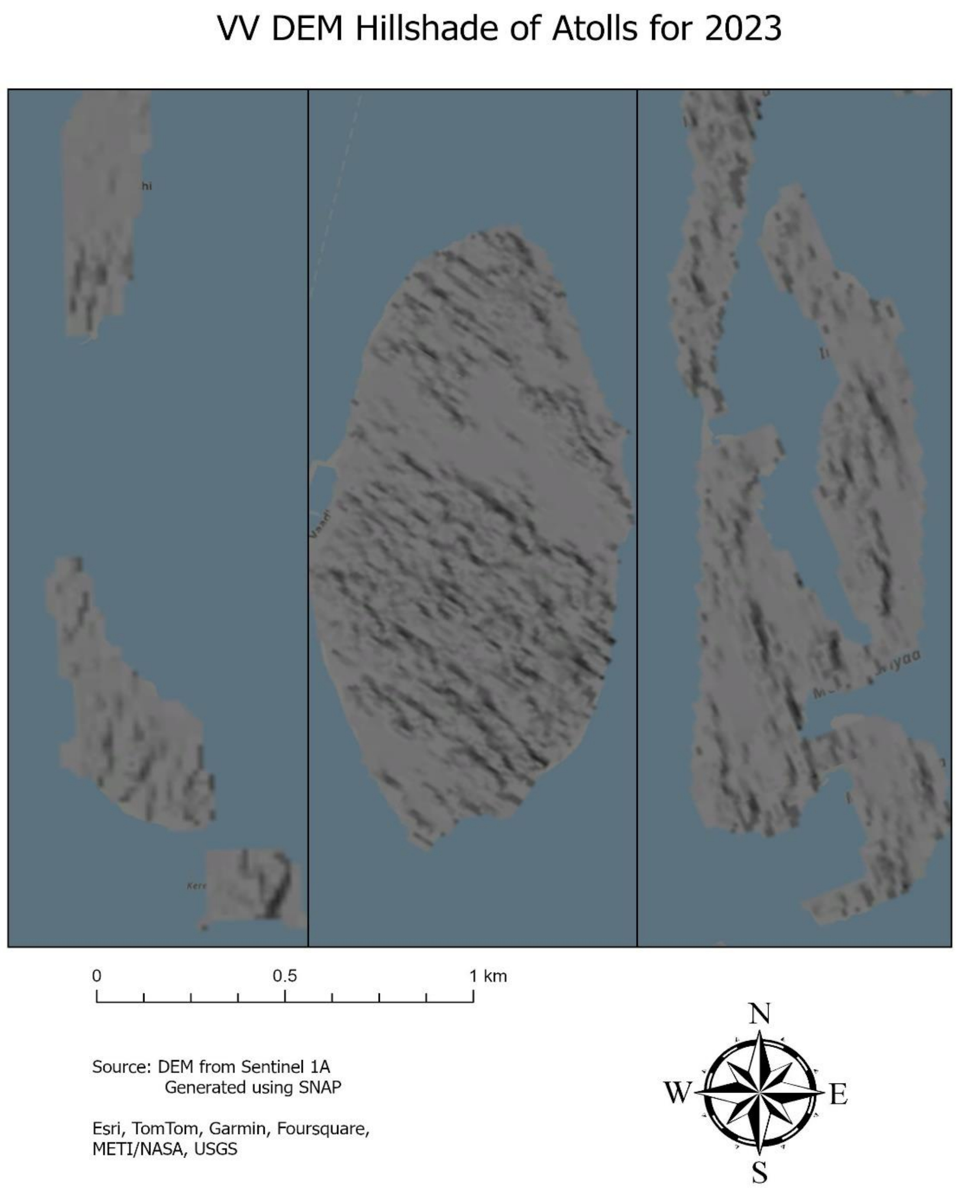


Figure 39: HillShade (VV Polarization) for the atolls (2023)

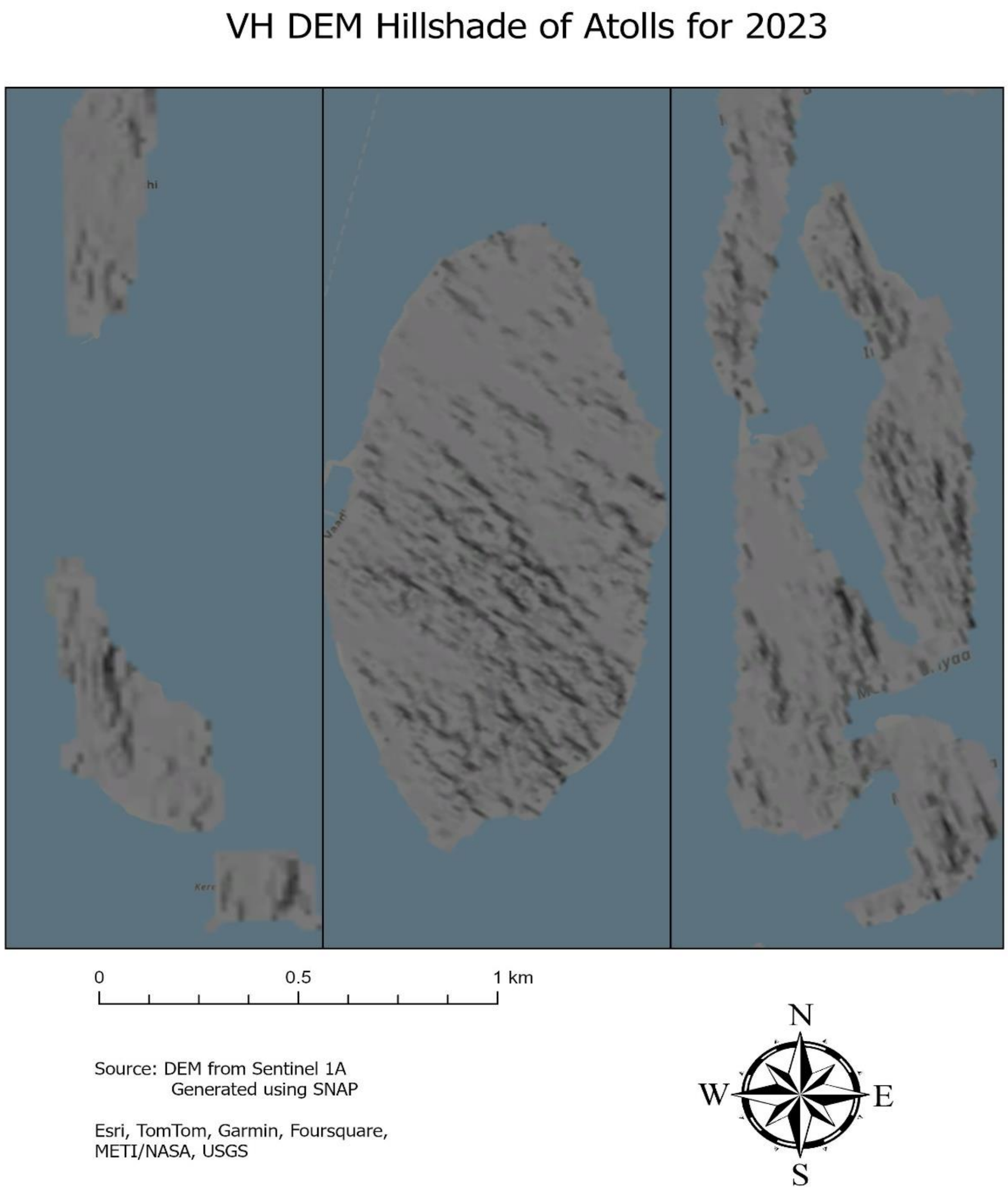


Figure 40: HillShade (VH Polarization) for the atolls (2023)

4 CONCLUSIONS

This internship project aimed to evaluate and understand SAR imagery for the development of a Digital Elevation Model (DEM) of 2 atolls and DEM from USGS for 1 atoll for the years 2023 and 2014 respectively. We conclude the following statements.

Atoll 1: For this imagery, VV polarization showed a higher degree of variation and elevation markers than VH polarization and the USGS DEM. Satellite imagery showed significant changes in urban areas and terrain from 2014 to 2023.

Atoll 2: The DEM of this Atoll showed that VH polarization had more variation and dispersion as compared to VV polarization and the USGS DEM, this is due to the presence of water around the island that showed in VH polarization and therefore proves that it is much more suitable for studying islands as compared to VV polarization. Satellite imagery showed very little urban development change between 2014 and 2023.

Atoll 3: VV polarization displayed 2 dominant elevation levels at 2m and 4m while USGS DEM and VH polarization showed just one dominant elevation level around 2.5m. The satellite images displayed no changes in the area between 2014 and 2023.

The use of synthetic Aperture Radar is incredibly useful for generating a Digital Elevation Model as displayed by the results. There were a few challenges and limitations of using this data such as temporal and geometrical decorrelation due to cloud coverage and other atmospheric disturbances. The Sentinel 1A SAR DEM images that were generated were clear and detailed as compared to the DEM imagery from USGS 2014.

NASA and ISRO (Indian Space Research Organization) plan to launch a satellite this year, to observe Earth's land and ice-covered surfaces with 12-day regularity for 3 years using SAR imagery (NISAR).

SOURCES

Alessandro Ferretti, Claudio Prati, and Fabio Rocca, Permanent scatterers in SAR interferometry IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 39, NO. 1, JANUARY 2001

Andrea Buono, Emanuele Ferrentino, Ferdinando Nunziata, Maurizio Migliaccio. Preserving natural ecosystems: atolls observed by partially polarimetric SAR satellite imagery. International Workshop on Metrology for the Sea Naples, Italy. 2020

D.J. Quincey, S.D. Richardson, A. Luckman, R.M. Lucas, J.M. Reynolds, M.J. Hambrey , N.F. Glasser Early recognition of glacial lake hazards in the Himalaya using remote sensing datasets, Global and Planetary Change Volume 56, Issue 1-2, Pages 137 – 152 March 2007

Ashraf M. Dewan, M. Monirul Islam, T. Kumamoto, M. Nishigaki. Evaluating flood hazard for land-use planning in greater Dhaka of Bangladesh using remote sensing and GIS techniques. Water Resources Management Volume 21, Issue 9, Pages 1601 – 1612 September 2007

Fausto Guzzetti, Alessandro Cesare Mondini, Mauro Cardinali, Federica Fiorucci, Michele Santangelo, Kang-Tsung Chang Landslide inventory maps: New tools for an old problem. Earth-Science Reviews Volume 112, Issues 1–2, April 2012, Pages 42-66

Massonnet, D. & Feigl, K. L. Radar interferometry and its application to changes in the Earth's surface November 1998 Reviews of Geophysics

P. Matgen , G. Schumann, J.-B. Henry, L. Hoffmann, L. Pfister. Integration of SAR-derived river inundation areas, high-precision topographic data and a river flow model toward near real-time flood management.

https://en.wikipedia.org/wiki/Geography_of_the_Maldives

https://www.eoportal.org/other-space-activities/snap-sentinel-application-platform#references

https://asf.alaska.edu/

https://dataspace.copernicus.eu/

https://sentinel.esa.int/web/sentinel/home

Orthophotos obtained from Google Earth satellite imagery.