Remote Sensing in DEM Studies on Hydrological Responses

PIFI Fellowship program 2021

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Outline

01 **Introduction**

Background and research objective

02 **Literature review**

Contain theories and basic ideas

03 **Study Area**

The location for object study

04 **Data Collection & Methodology**

How collect and process the data

05 **Results and Discussion**

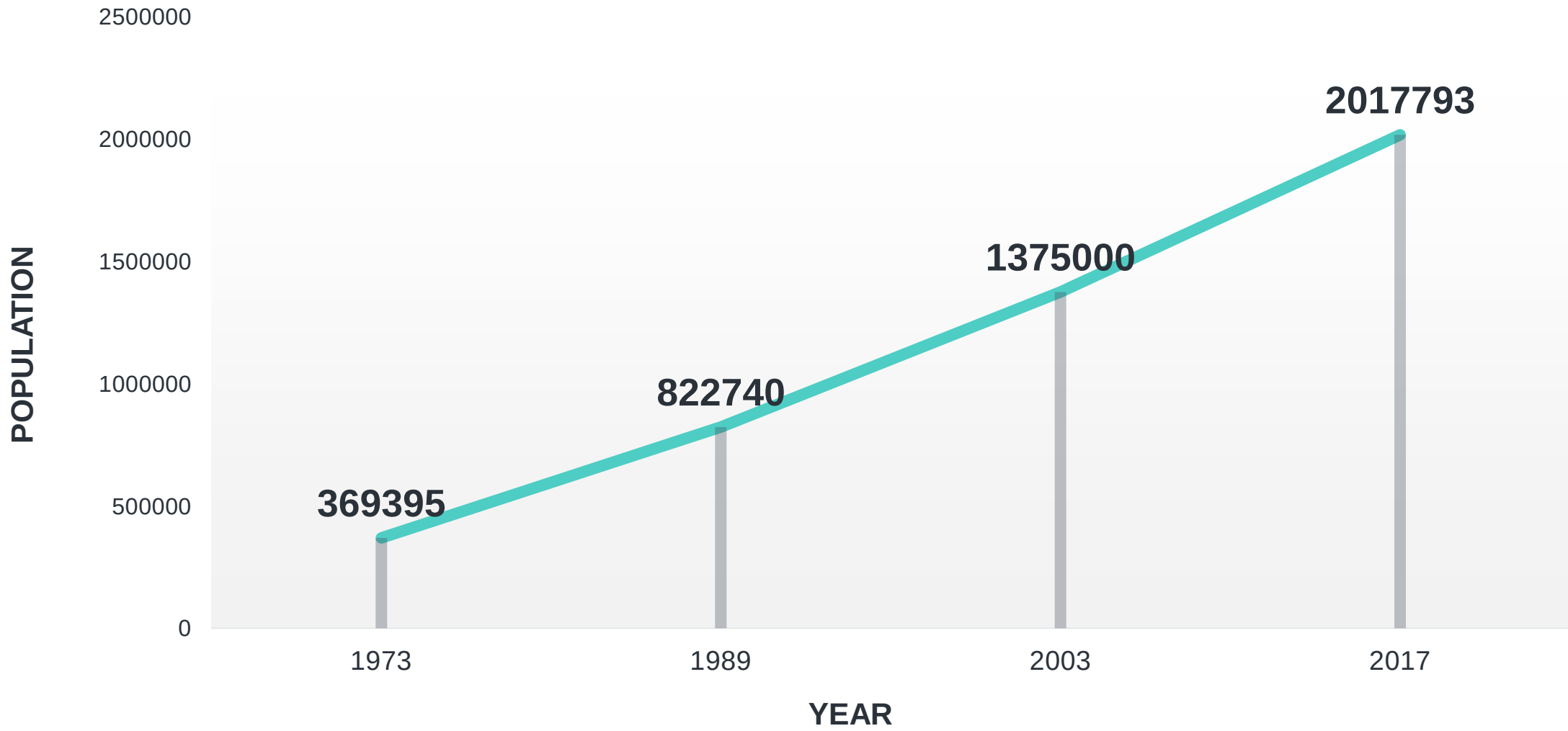
What the major finding on this study

06 **Conclusions**

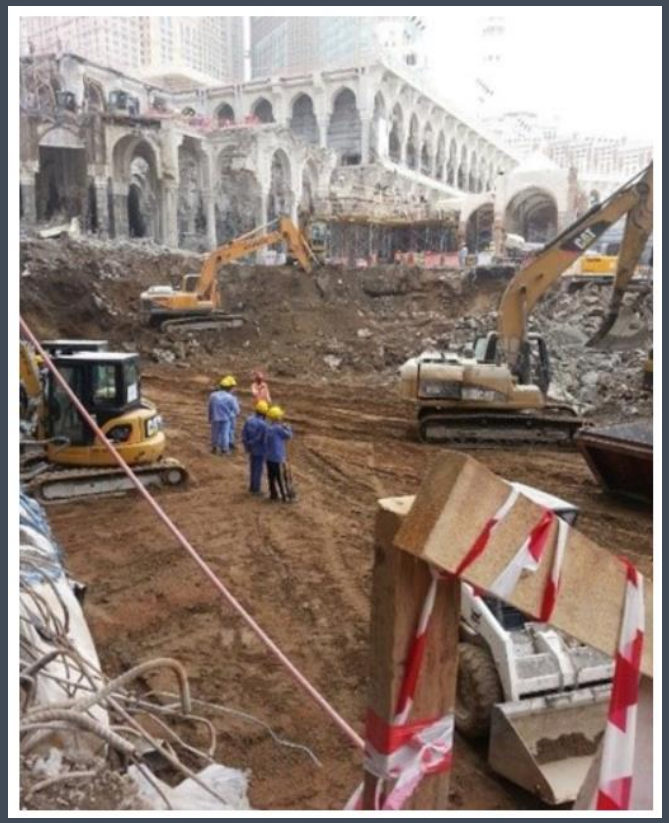
The Sum up of this study

Ministry of Municipal and Rural Affairs KSA (2019)

Urbanization in Makkah City



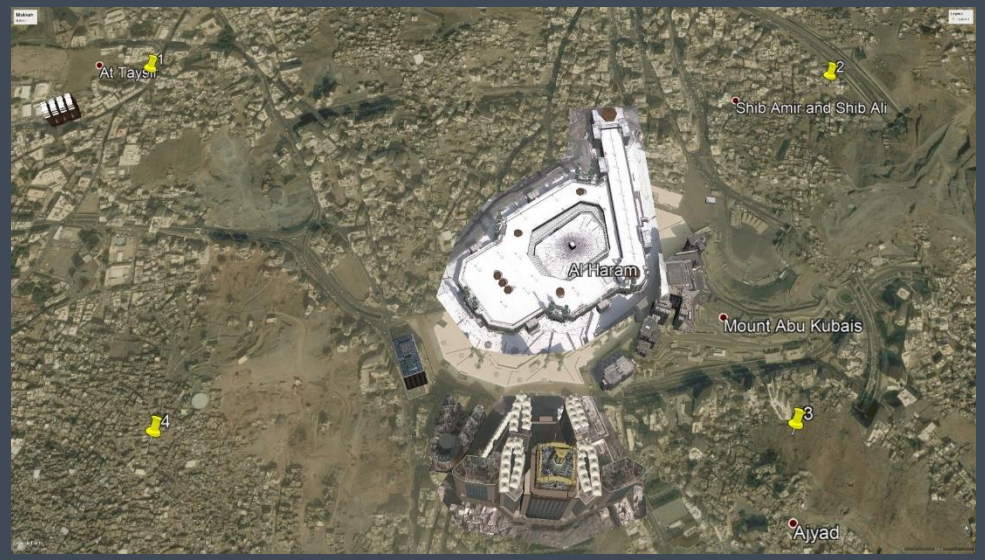
Makkah City projects



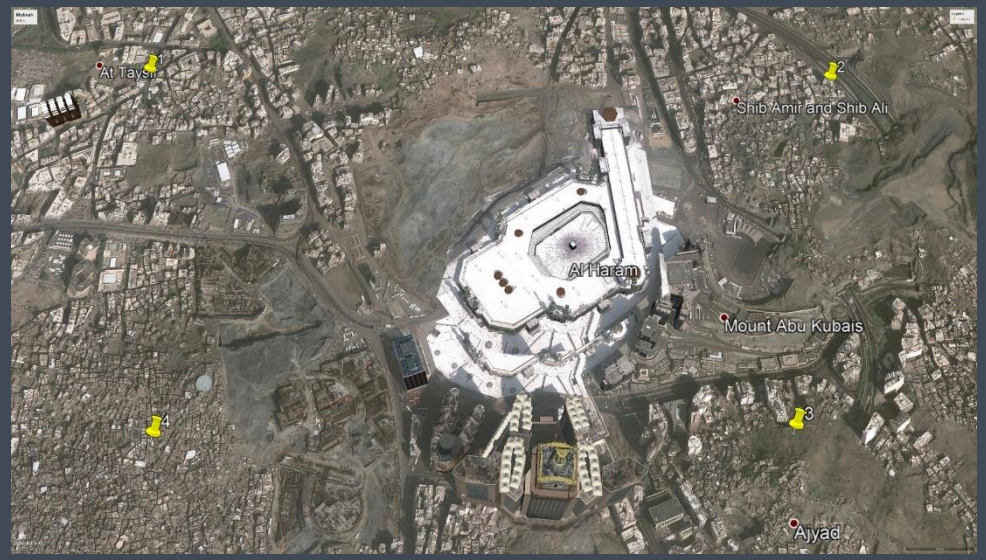
Source: Saudi Geological Surveys

Al-Haram Area Expansion

2005



2010



2020

2015

Source:
Google earth

Research Questions

DEM

What version of DEM that best represents the current condition??

Hydrological Response

What are the consequences of the changes in the DEM on the hydrological response of adjacent basins in Makkah City??

Research Objectives

Define high Accurate DEM

To define the most accurate DEM of Makkah City that represent the current condition

Hydrological Response

To study the impact of anthropogenic activities on hydrological response such as changes flow direction and stream network, and development of GIUH of the basin in Makkah City

2

Literature Review

Anthropogenic Activities

- Hydrological condition of watershed can be influenced by human activities or anthropogenic activities and climate change (Yang et al., 2017; Arthington et al., 2012).
- Anthropogenic activities in the Lancang River basin in China has a 55-60% contribution greater than climate change (Tang et al. 2021).
- Anthropogenic activities caused changes of streamflow and geomorphological of the watershed (Bao et al., 2012; Kong et al., 2016; 2019; Han et al., 2019; Xie et al., 2019),

DEM Study

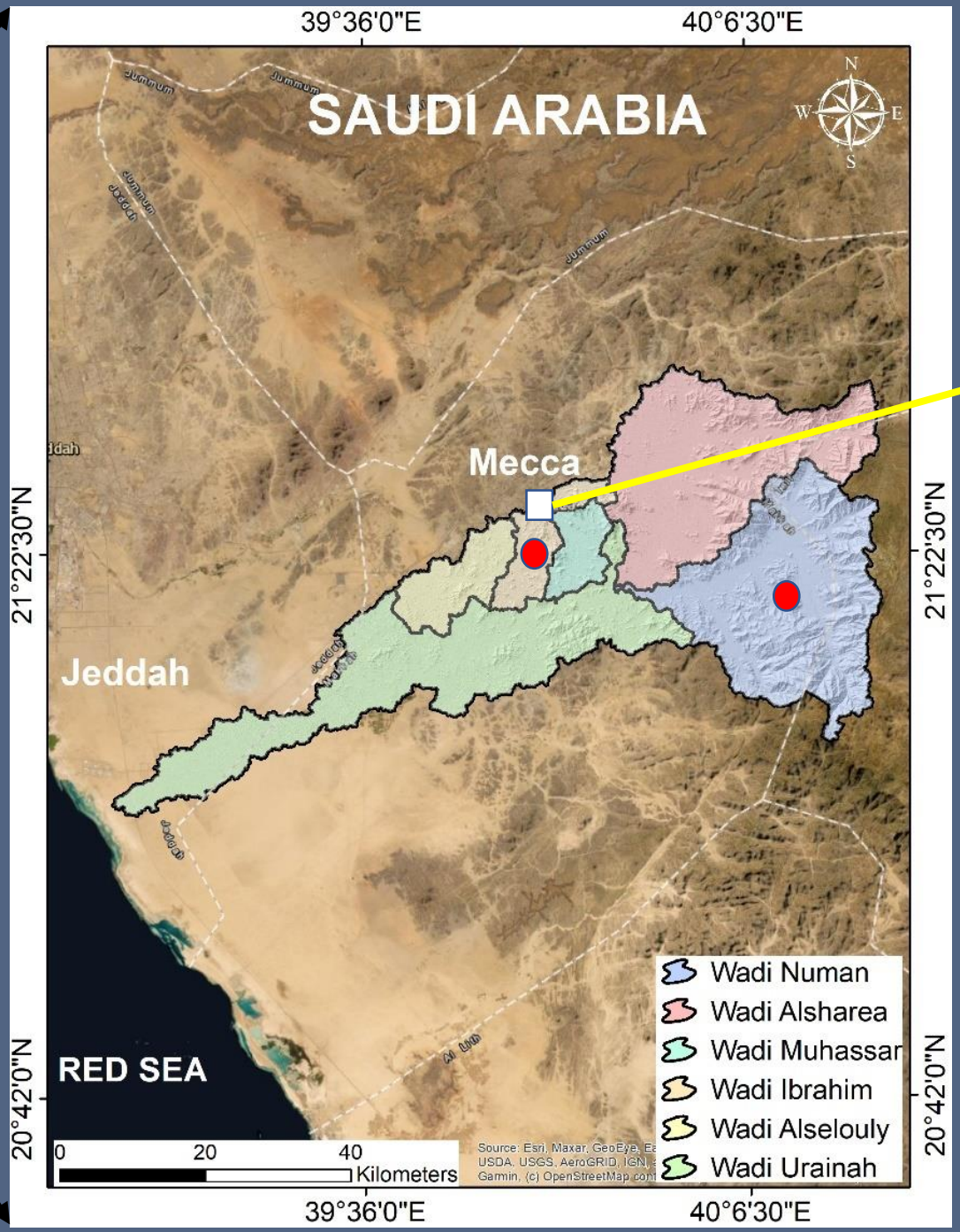
- DEM = Digital Elevation Model
- DEM is very important for watershed delineation (Jenson, 1991), stream network extraction (Tarboton, 1997), surface flow-path mapping (Erskine et al., 2006), environmental studies (Jing et al., 2014), and for study the different types of natural hazards (Boreggio et al., 2018).

DEM	Parameter				
	Resolution	Sources	Acquisition Year	Released Year	Band
SRTM	30 m	NASA	2000	2013	C
ALOS	12.5 m	JAXA	2007	2014	L
Copernicus	30 m	ESA	2011-2014	2021	X
Sentinel-1	13.5 m	ESA	2015-now	2015	C

3

Study Area

Study Area



Al-Haram Mosque

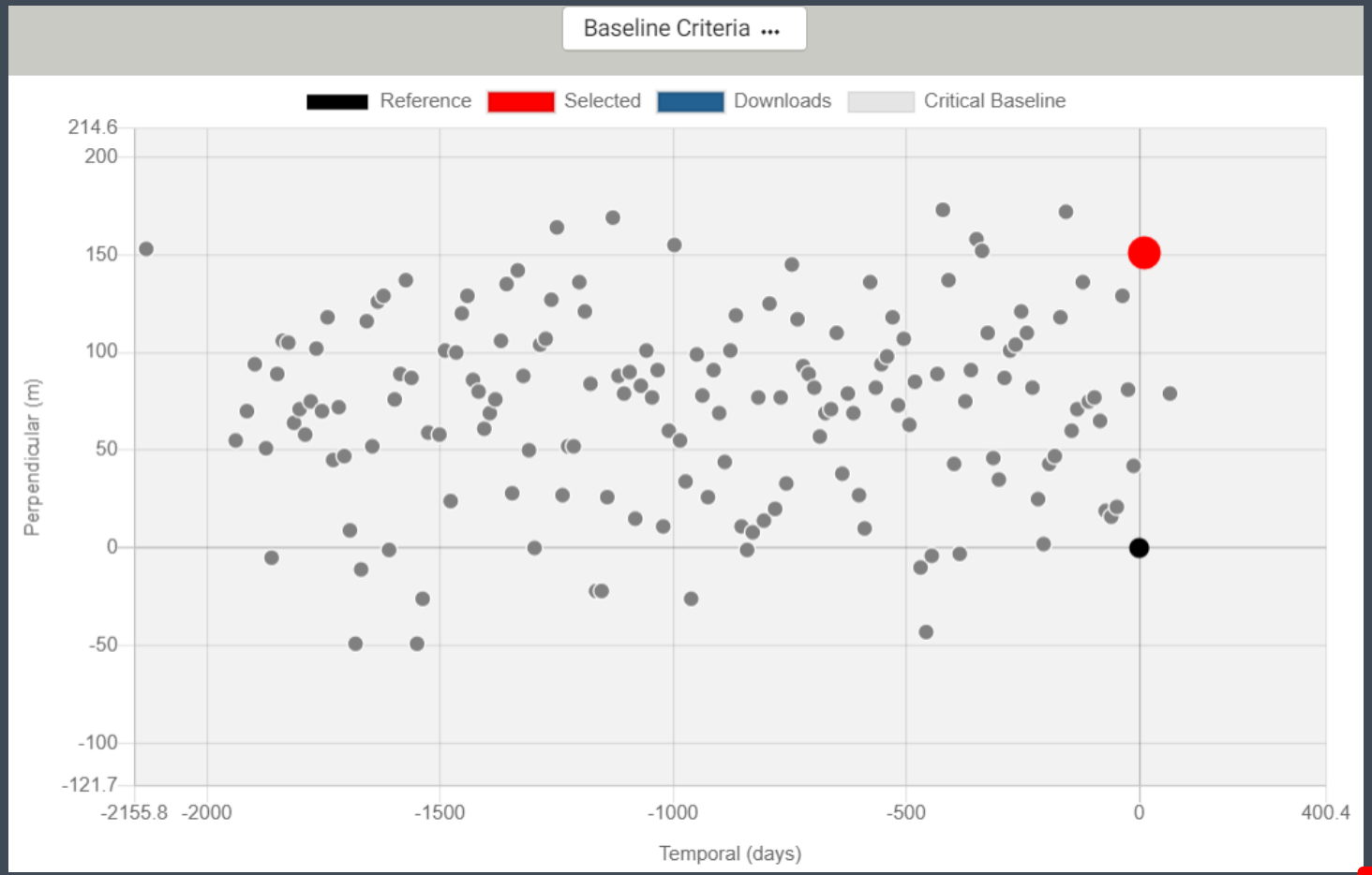
Morphometric Parameters	Wadi Nouman	Wadi Ibrahim
Elevation (m)	282 - 2605	213 - 949
Area (km)	678.6	110.8
Perimeter (km)	210.7	107.2

Source: Author

4

Data Collection and Methodology

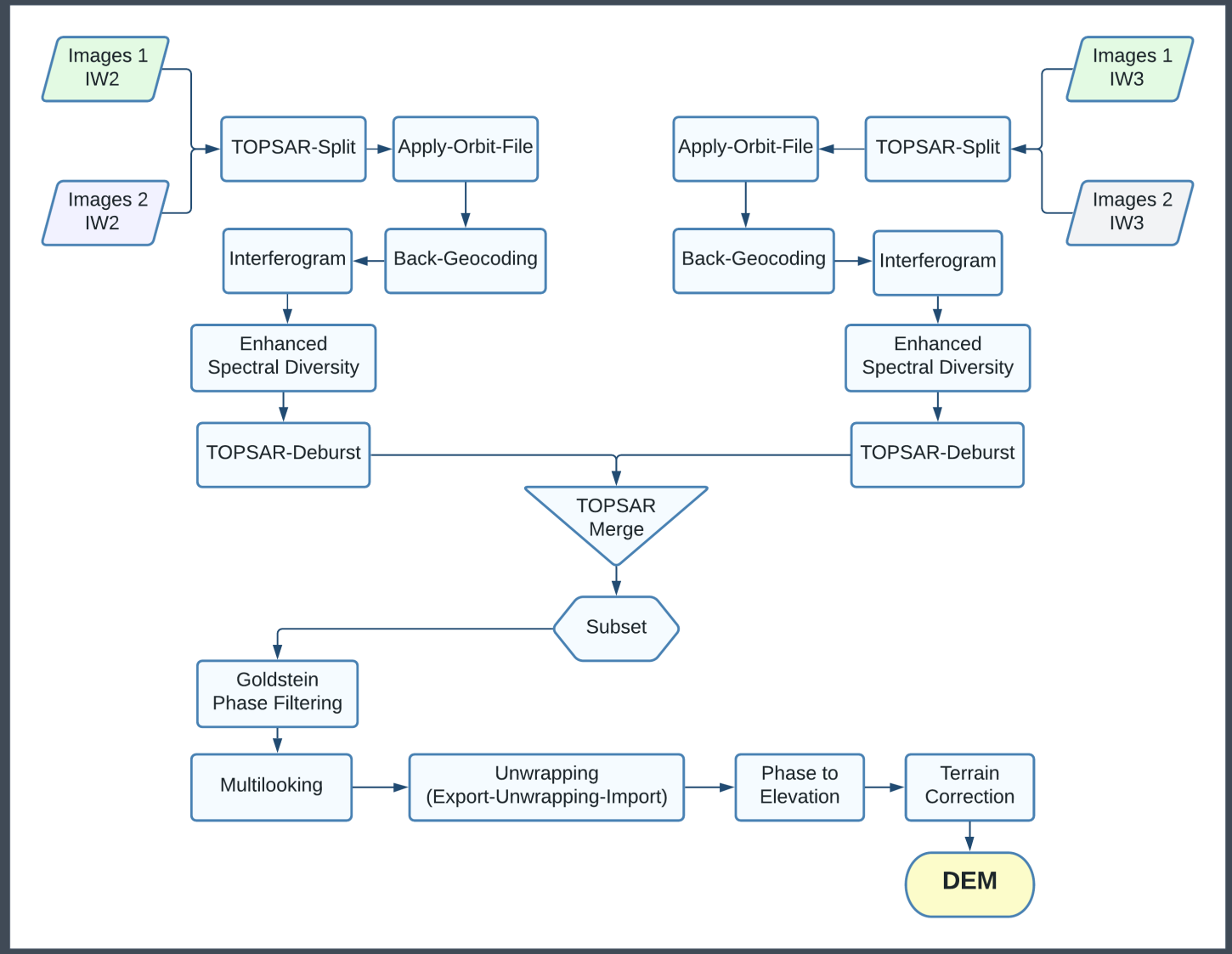
Data Collection of Sentinel-1 DEM

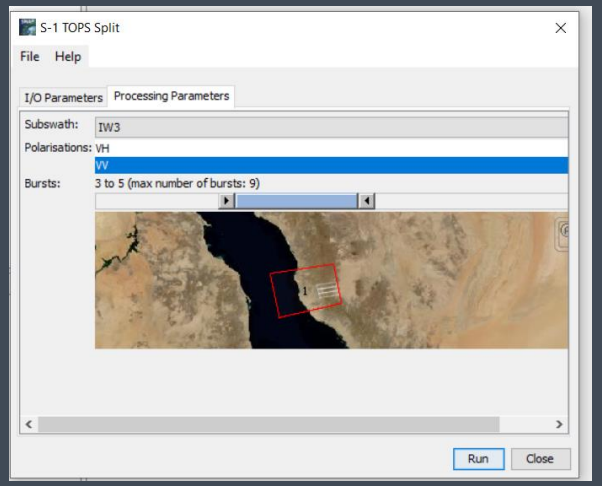


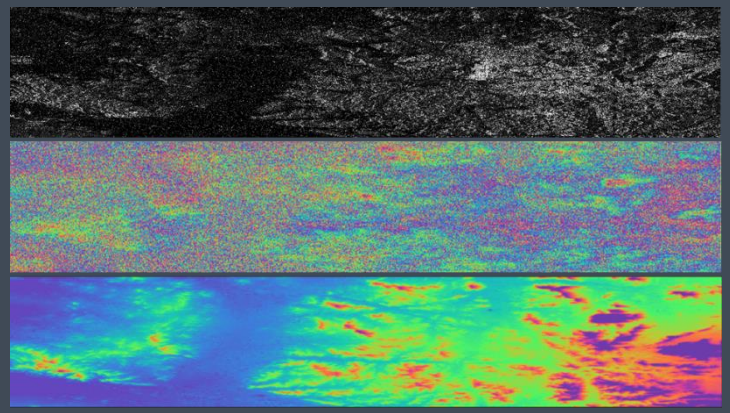
https://baseline.asf.alaska.edu

Type	Date	Track	Orbit	Temp_b (days)	Perp_b (m)	Coherence
Master	02-Sep-17	14	7215	0	0	1
Slave	14-Sep-17	14	7390	12	136	0.88
Master	28-Aug-18	14	12465	0	0	1
Slave	15-Oct-18	14	13165	48	158	0.83
Master	21-Sep-18	14	12815	0	0	1
Slave	15-Oct-18	14	13165	24	107	0.89
Master	15-Oct-18	14	13165	0	0	1
Slave	08-Nov-18	14	13515	24	191	0.82
Master	27-Oct-18	14	13340	0	0	1
Slave	08-Nov-18	14	13515	12	143	0.87
Master	22-Sep-20	14	23490	0	0	1
Slave	16-Oct-20	14	23840	24	175	0.83
Master	21-Nov-20	14	24365	0	0	1

Flowchart of Sentinel-1 DEM

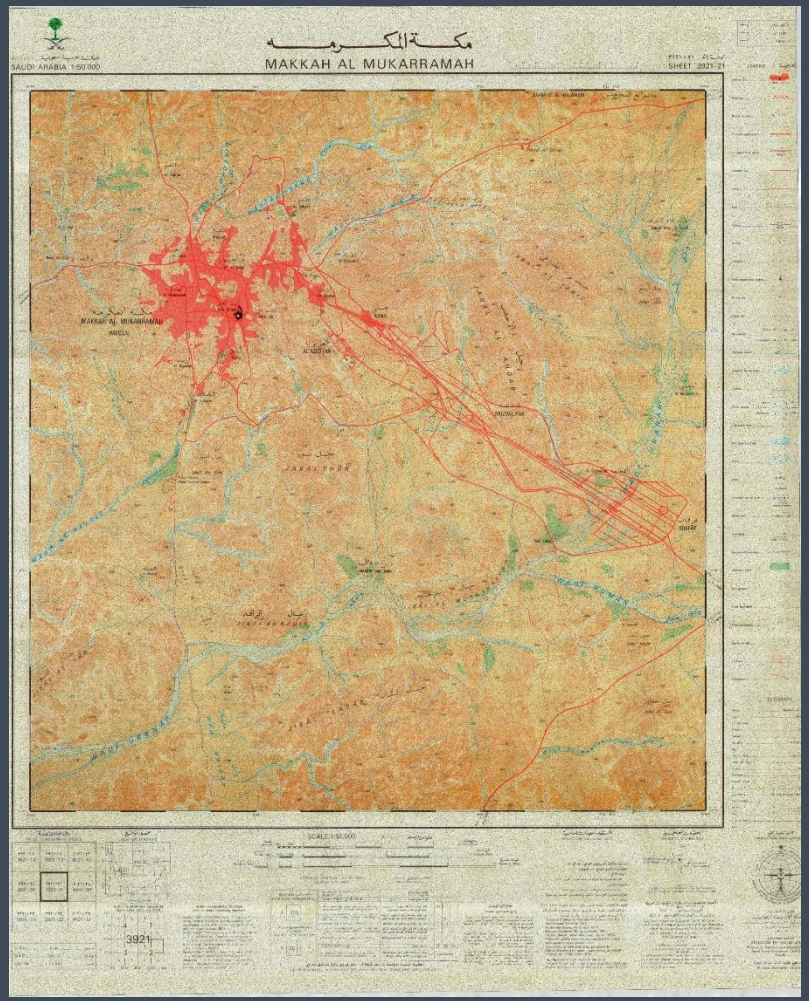




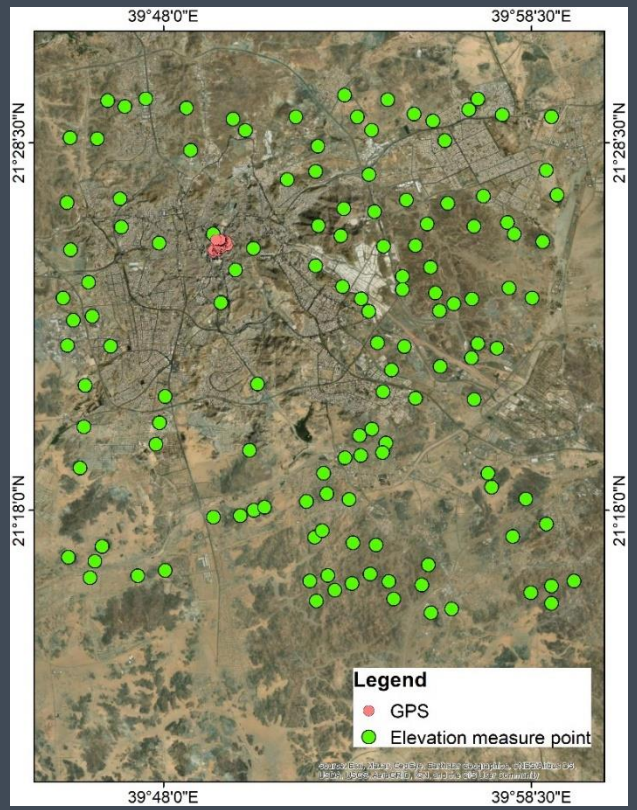


DEM Validation

Topographic map



Georeferencing in GIS



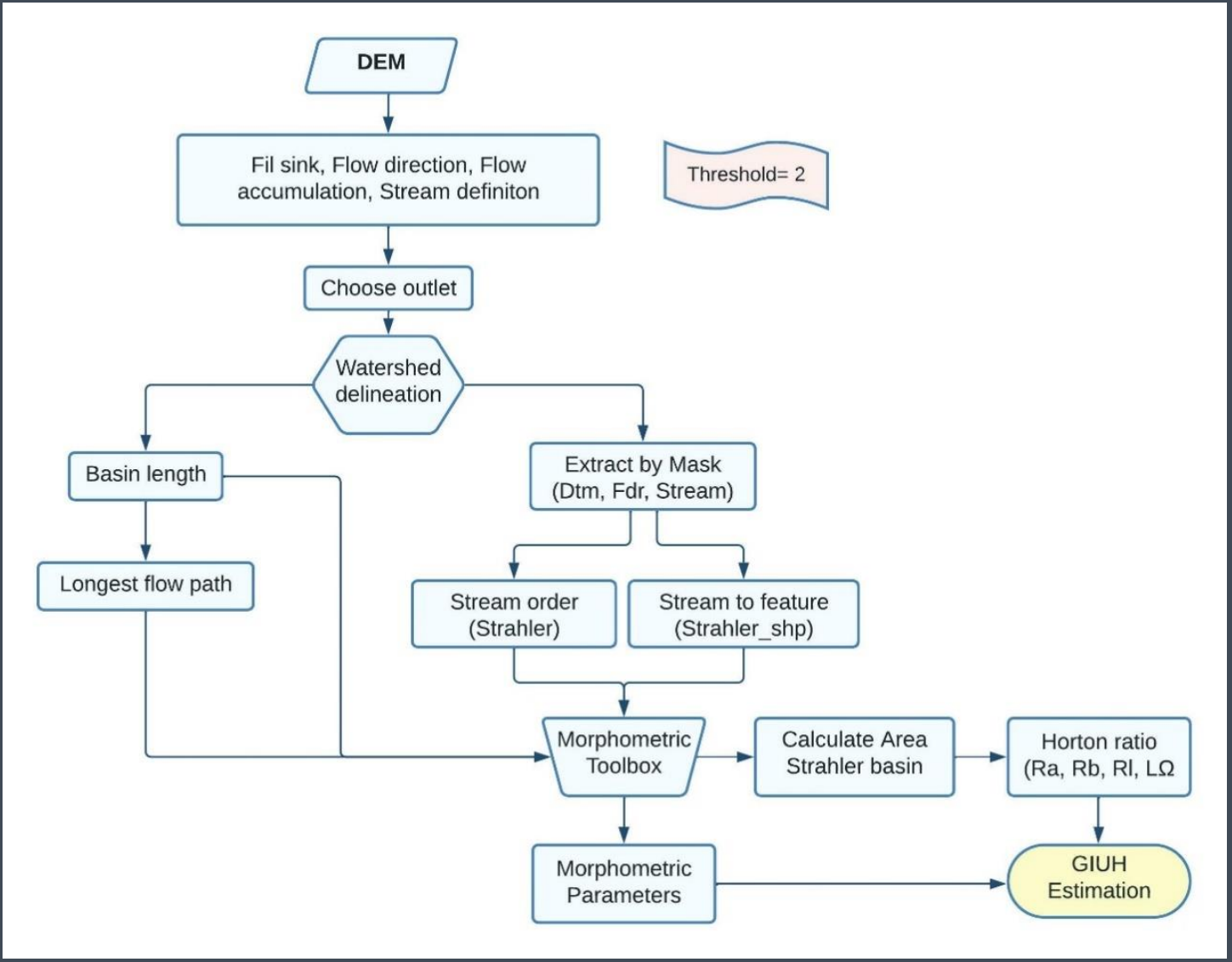
Statistical assessment

$$Z_{error} = Z_{Topho} - Z_{DEM}$$

$$MAE = \sum_{i=1}^{n} \frac{|Z_{error}|}{n}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (Z_{error})^2}{n}}$$

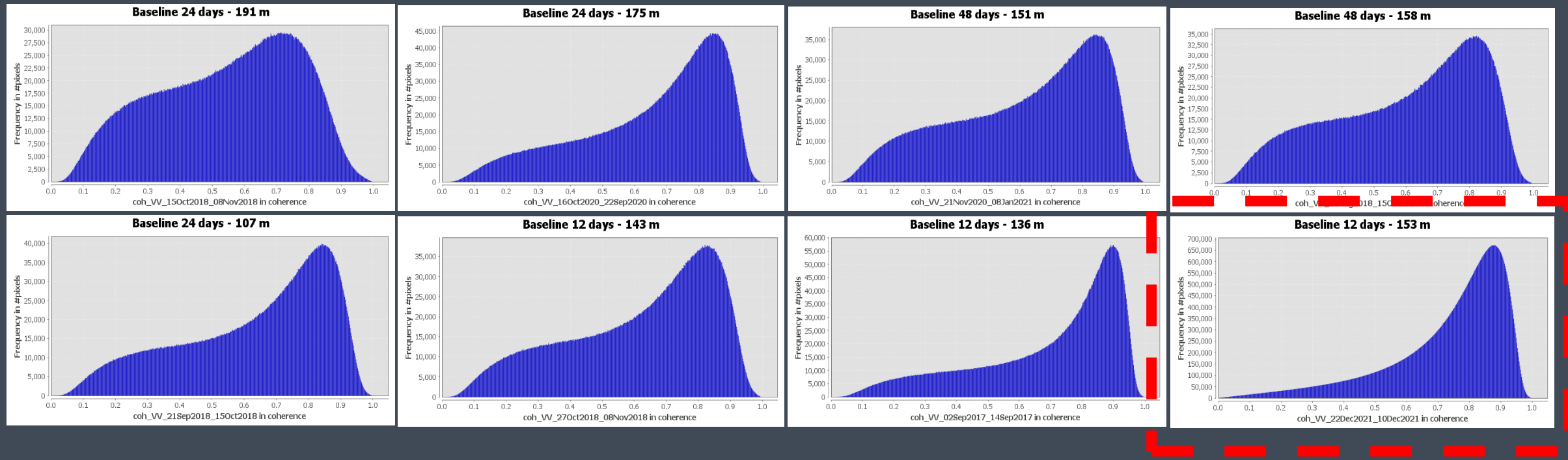
Morphometric Parameter and GIUH Estimation Flowchart



5

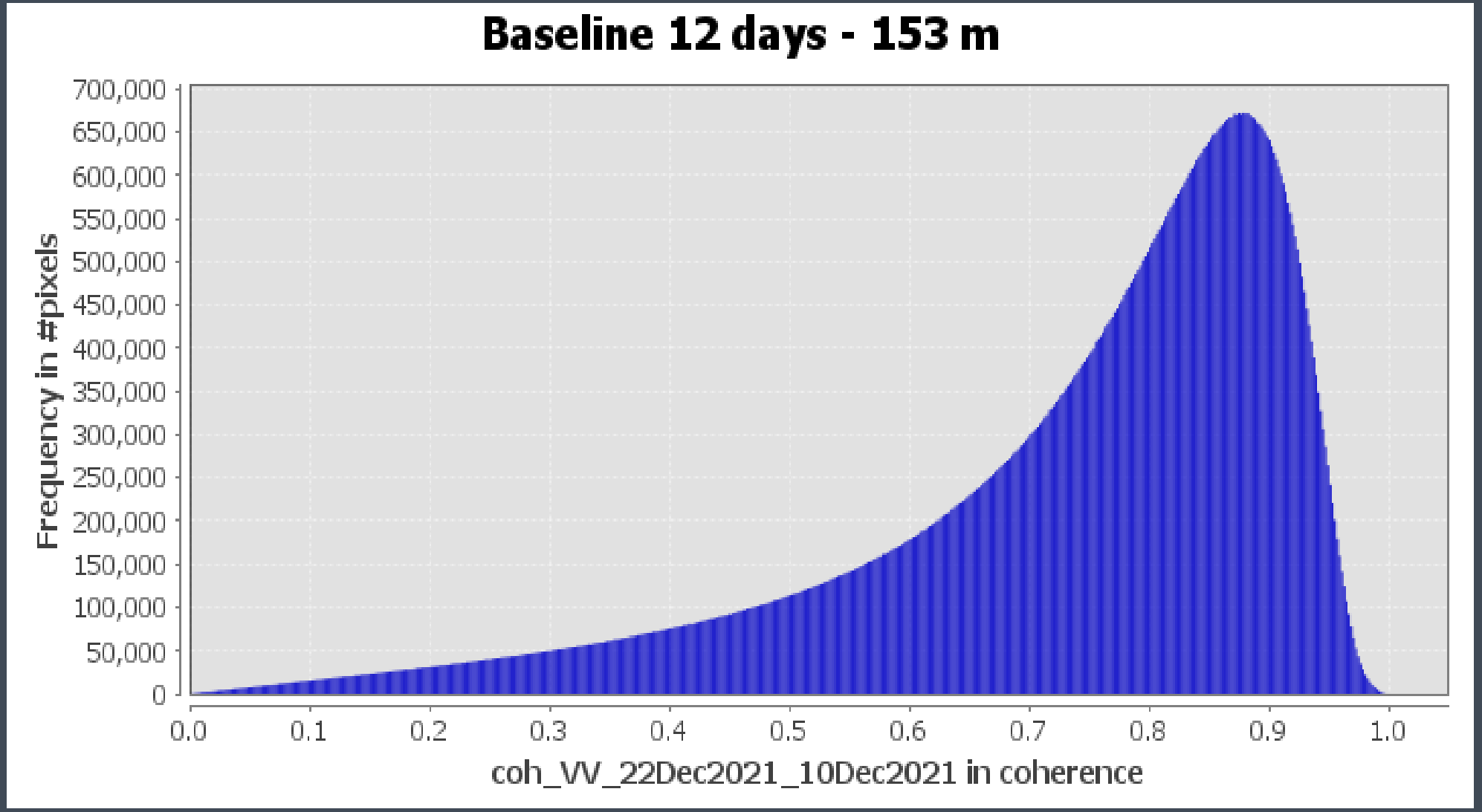
Results and Discussions

Pair Selection of Sentinel-1 DEM



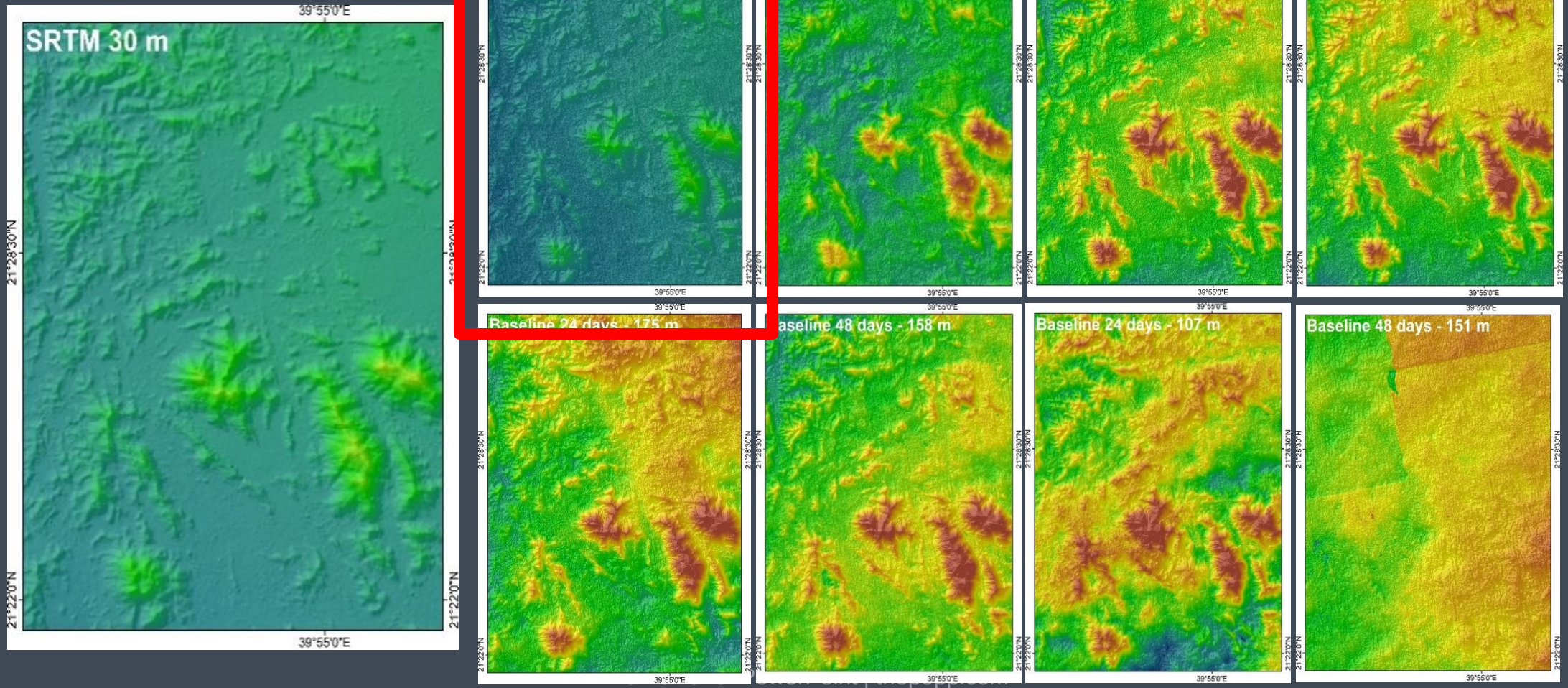
Good results= Small temporal and high perpendicular baseline

Best Coherence



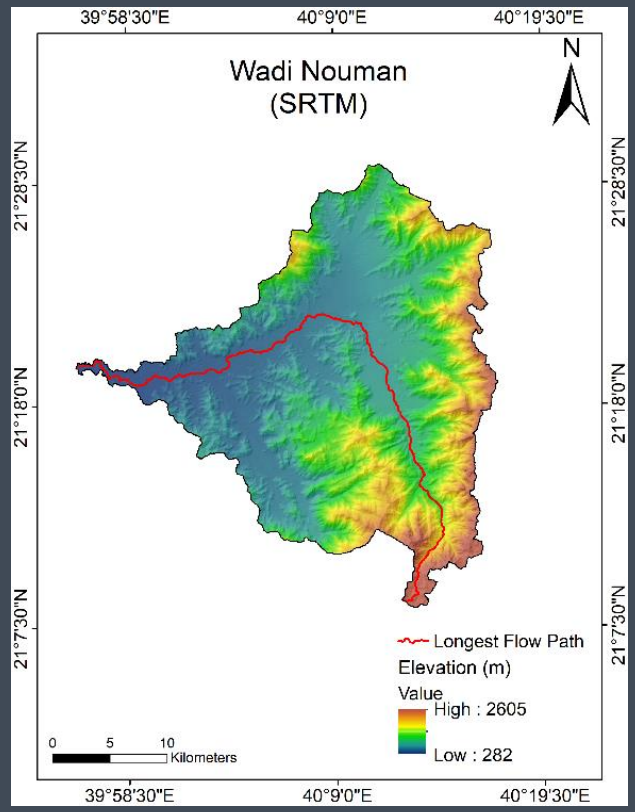
Results – Sentinel-1 DEM

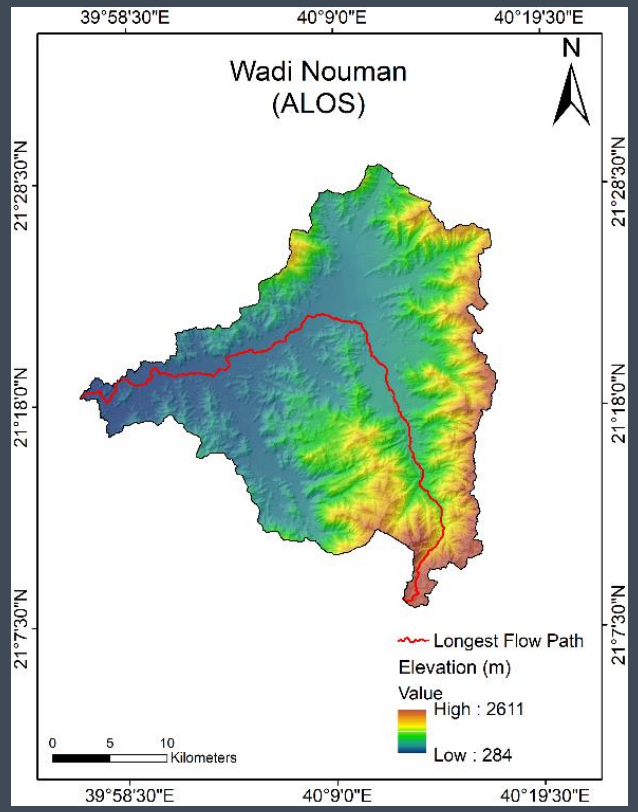
Reference DEM

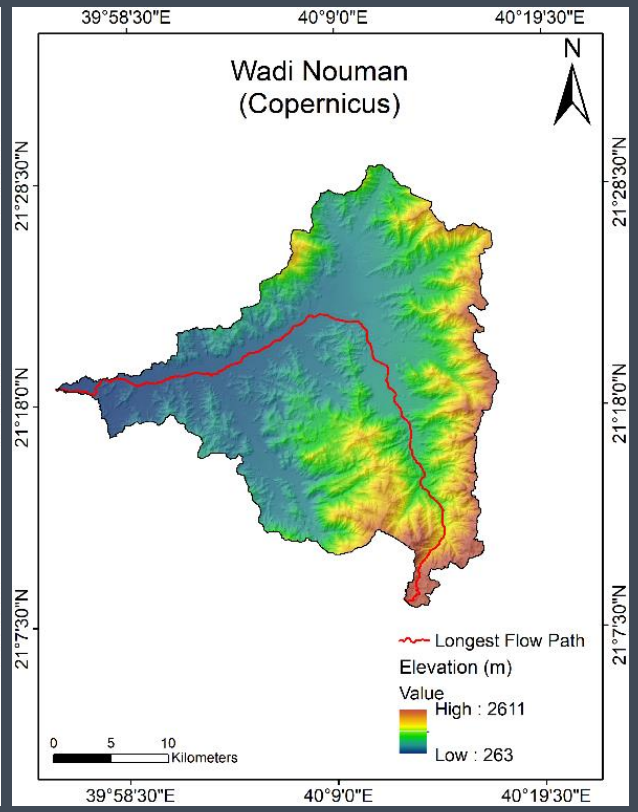


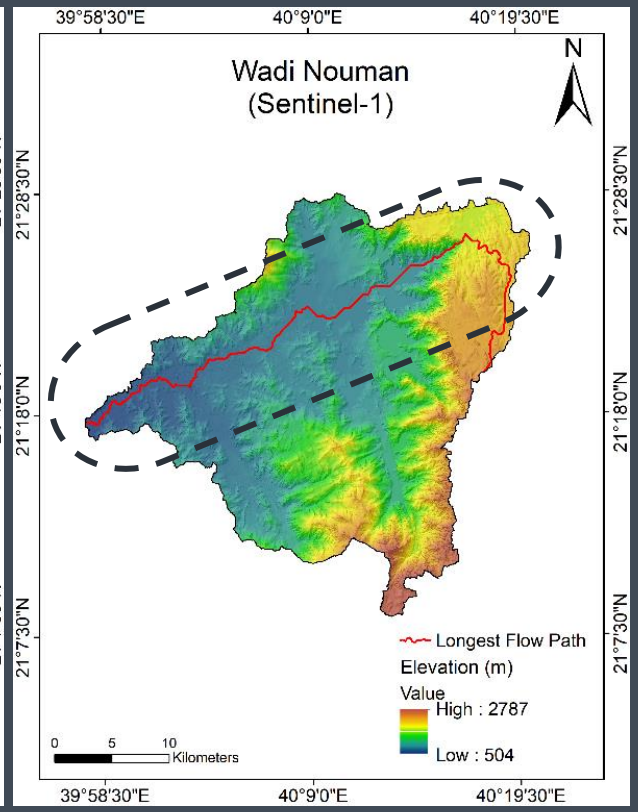
Results - DEM Comparison

Wadi Nouman - Elevation



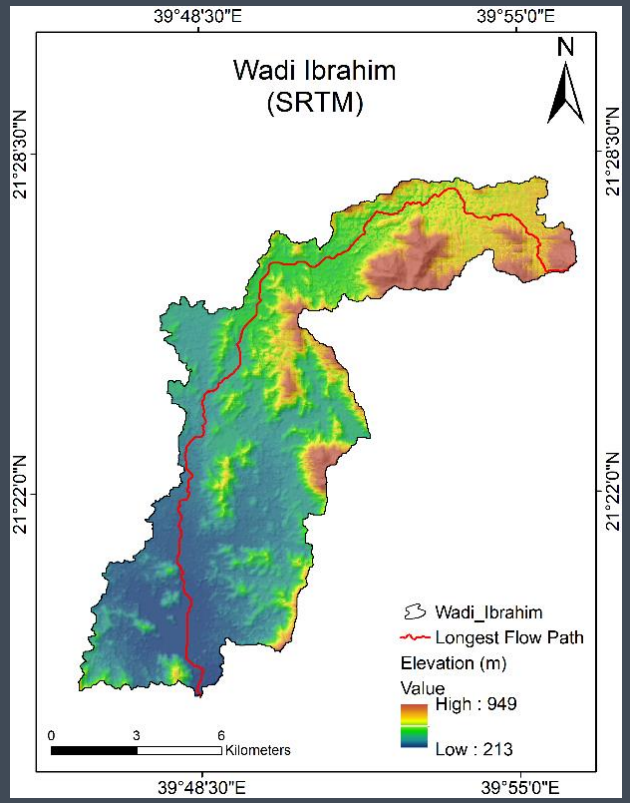


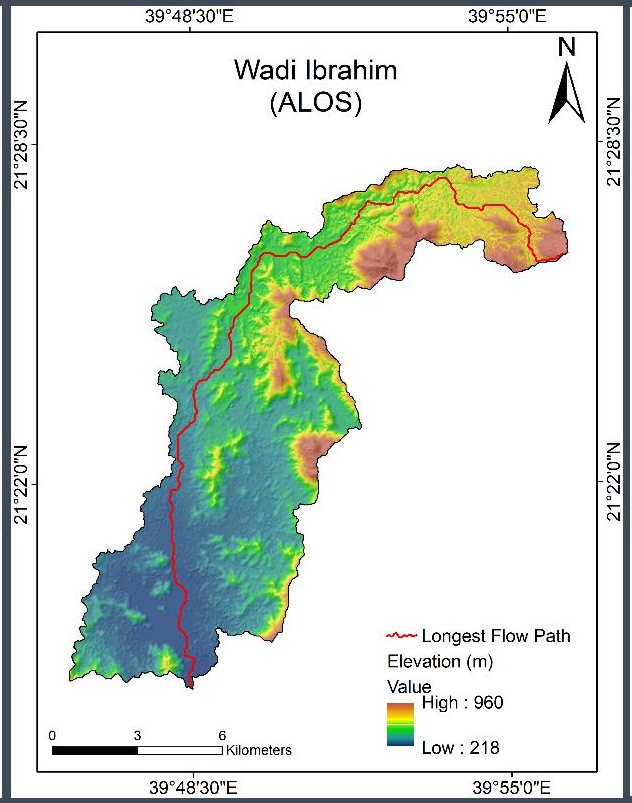


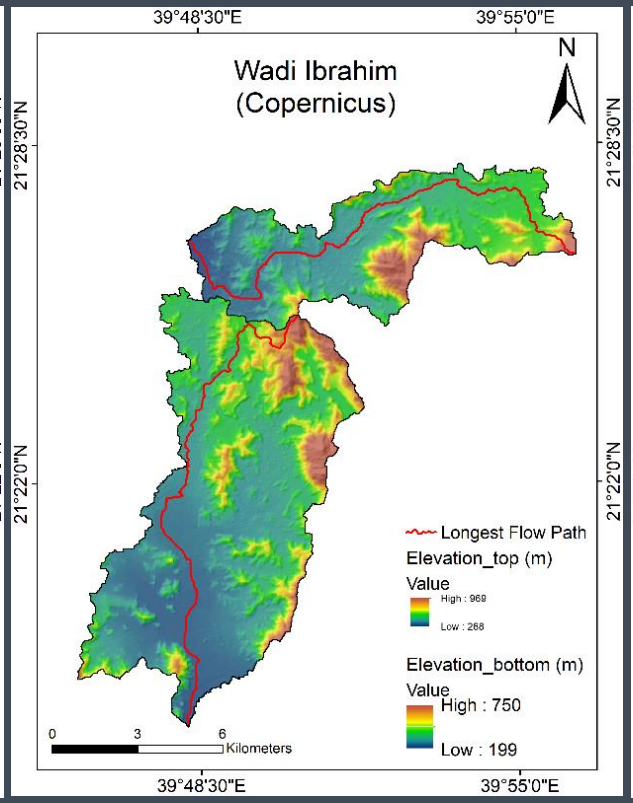


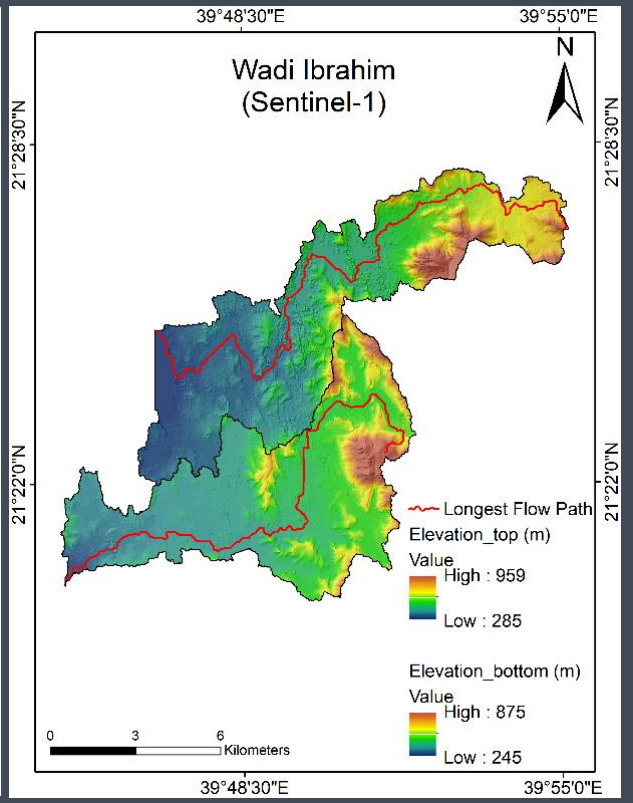
Results - DEM Comparison

Wadi Ibrahim - elevation

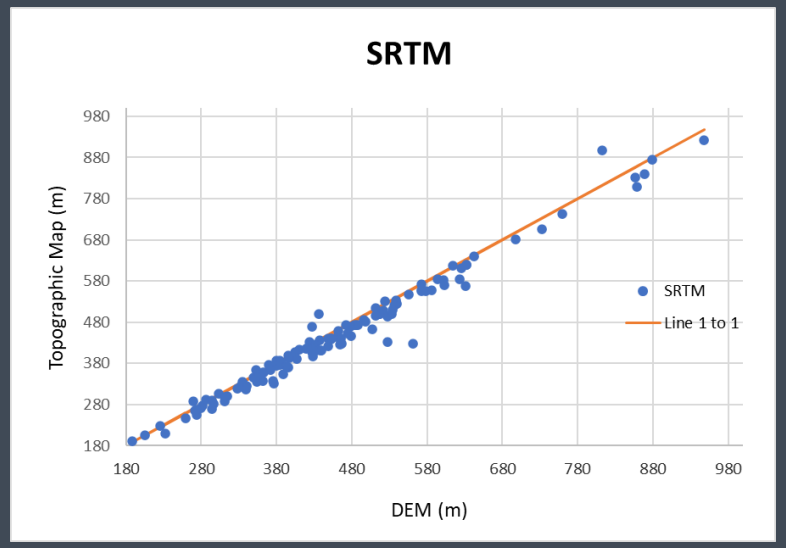


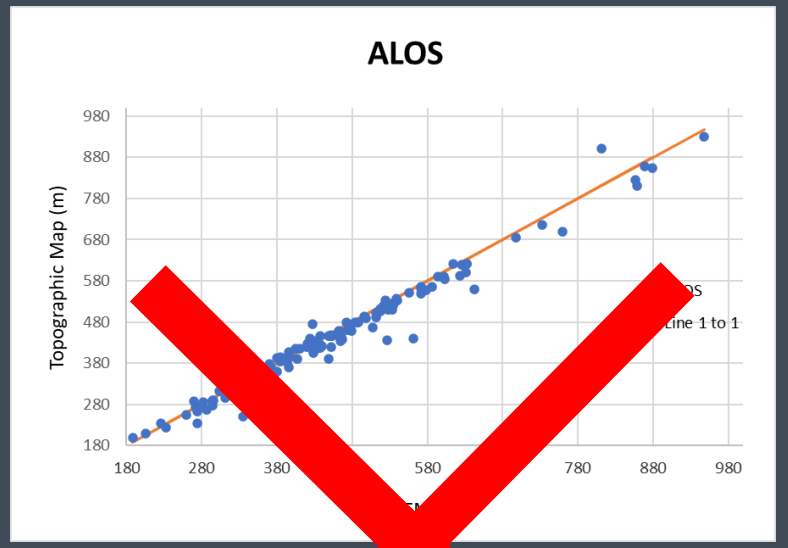


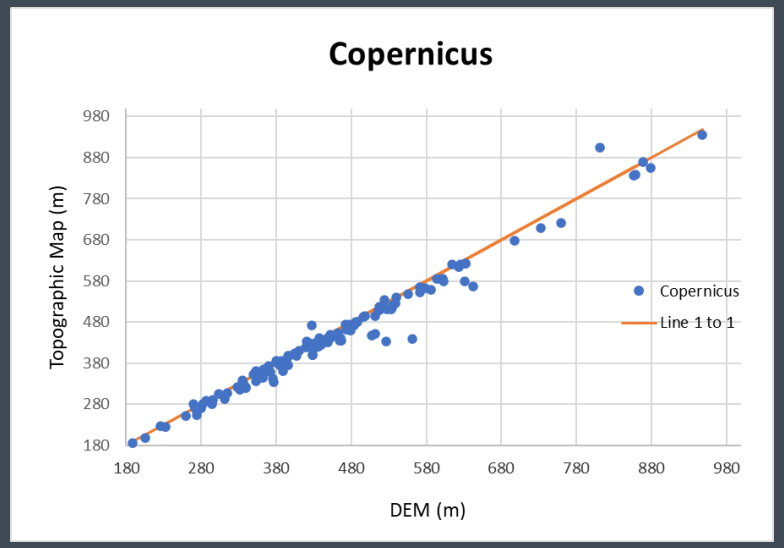


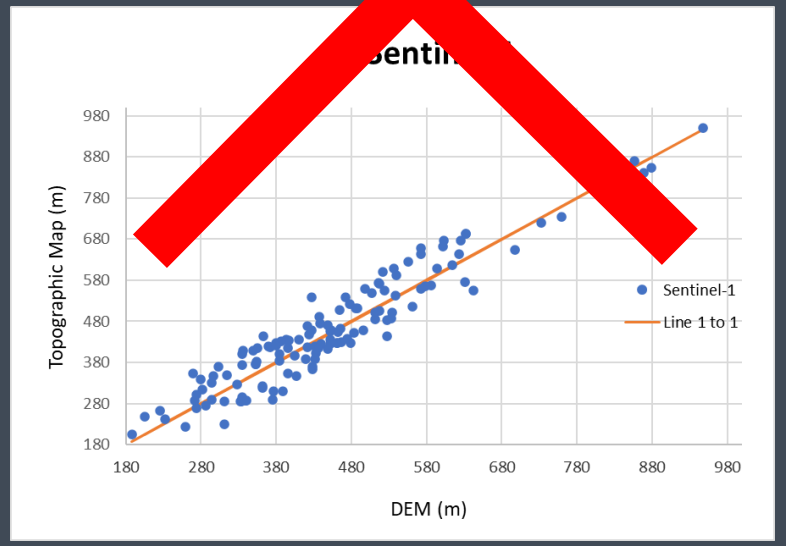


Results – Validation









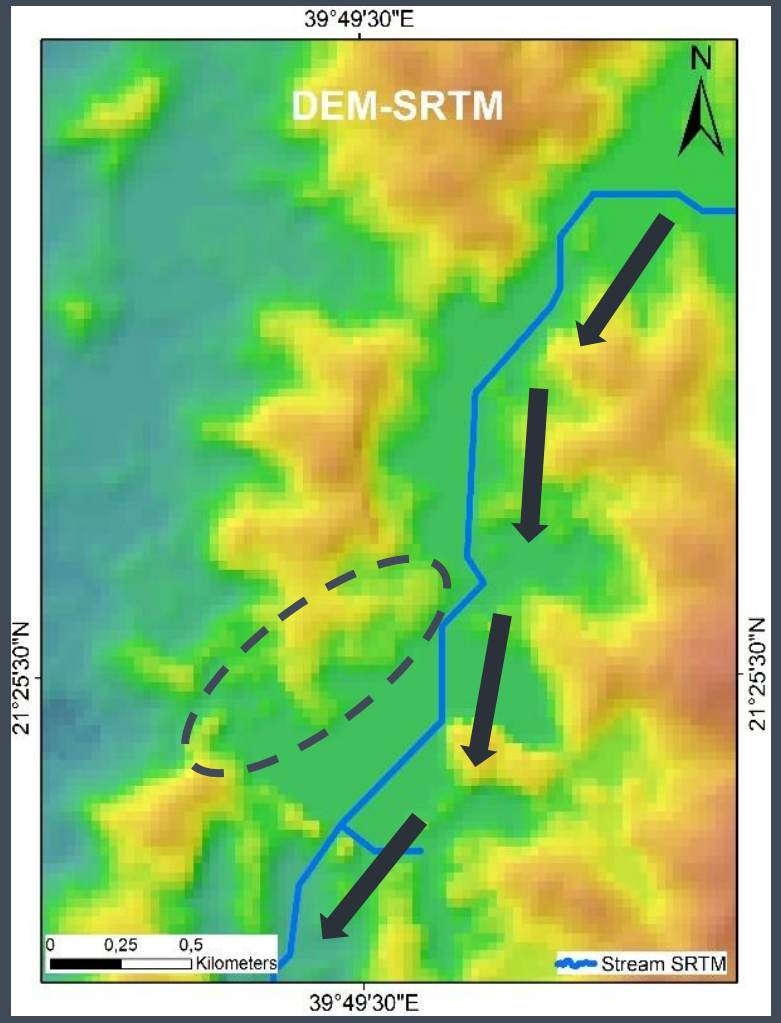
DEM vs Topo map and GPS

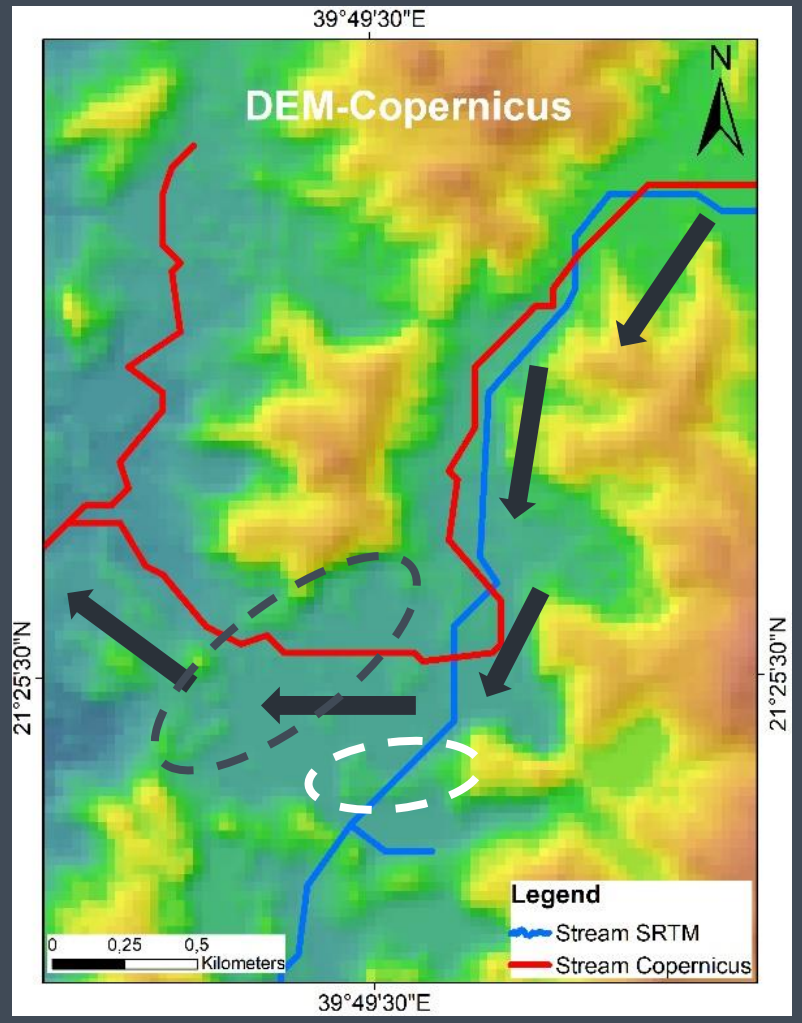
- ✓ Copernicus and SRTM have the highest accuracy with correlation coefficient = 0.9788 and 0.9765, and the lowest RMSE = 3.89 m and 4.23 m, respectively.
- ✓ Sentinel-1 and ALO have the less accuracy with correlation coefficient = 0.9028 m and 0.9687 and highest RMSE 6.31 and 4.27, respectively.

SRTM vs Copernicus - Hillshade

Old DEM

(2000)





New DEM

(2011-2014)

SRTM vs Copernicus – Basemap

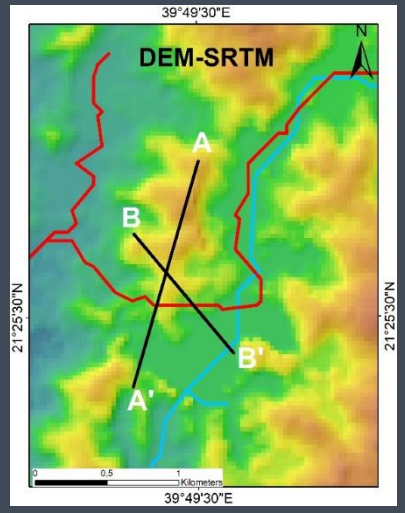
Blue = SRTM

Red = Copernicus

2004

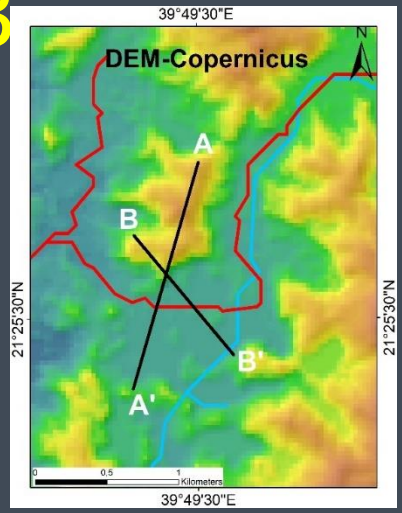
2021

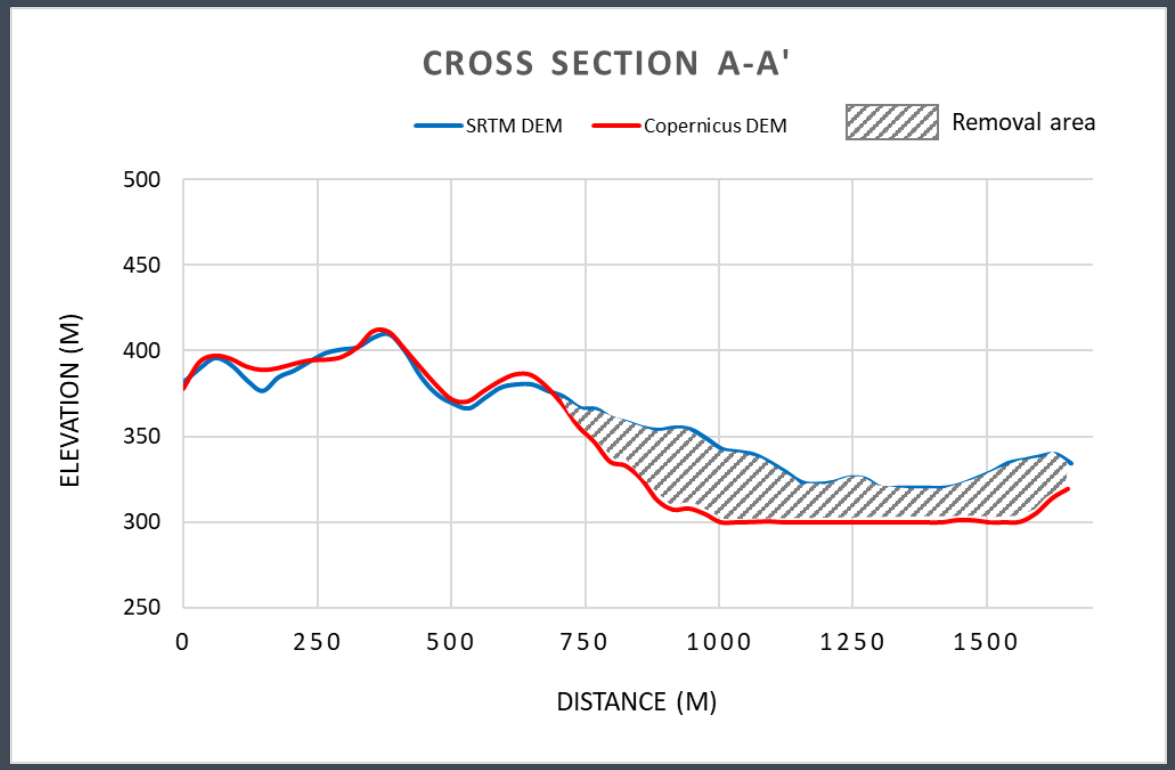
SRTM vs Copernicus – Cross Section 3

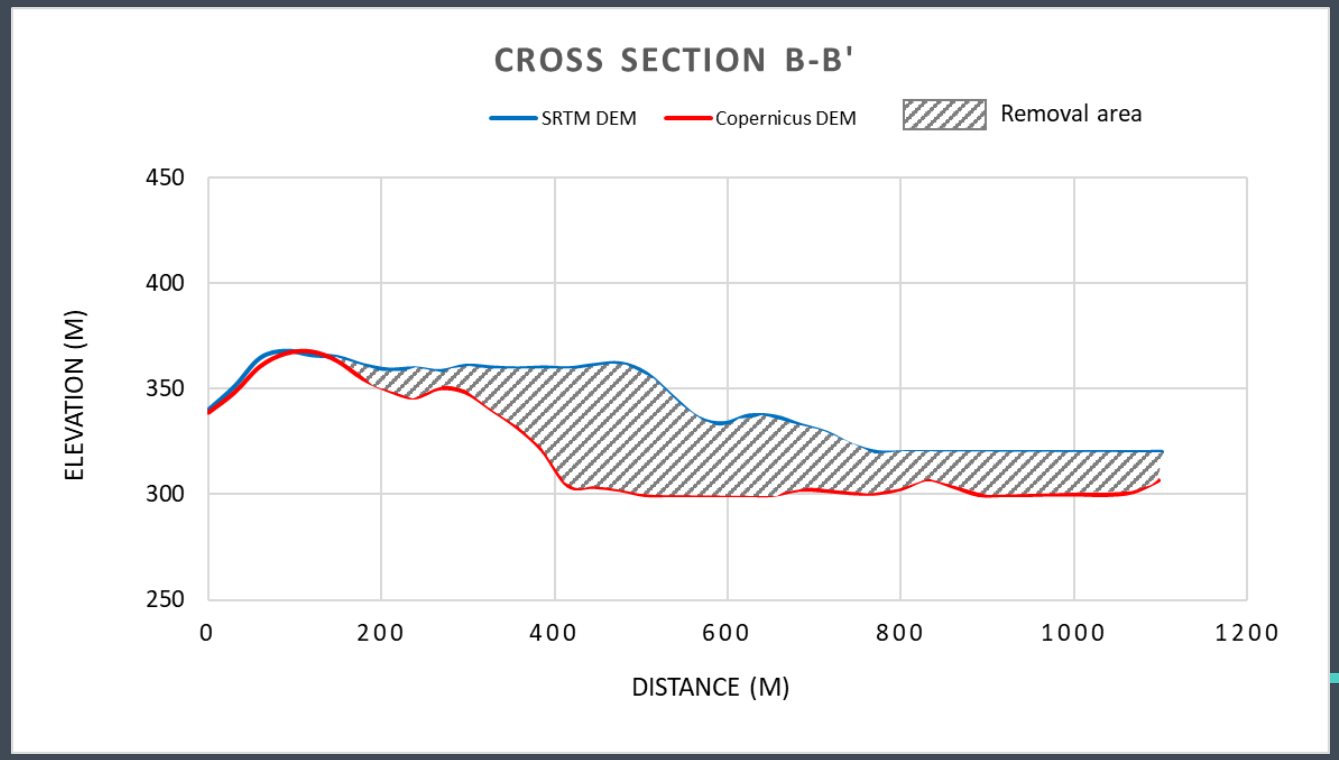


Old DEM

New DEM







Urban Area

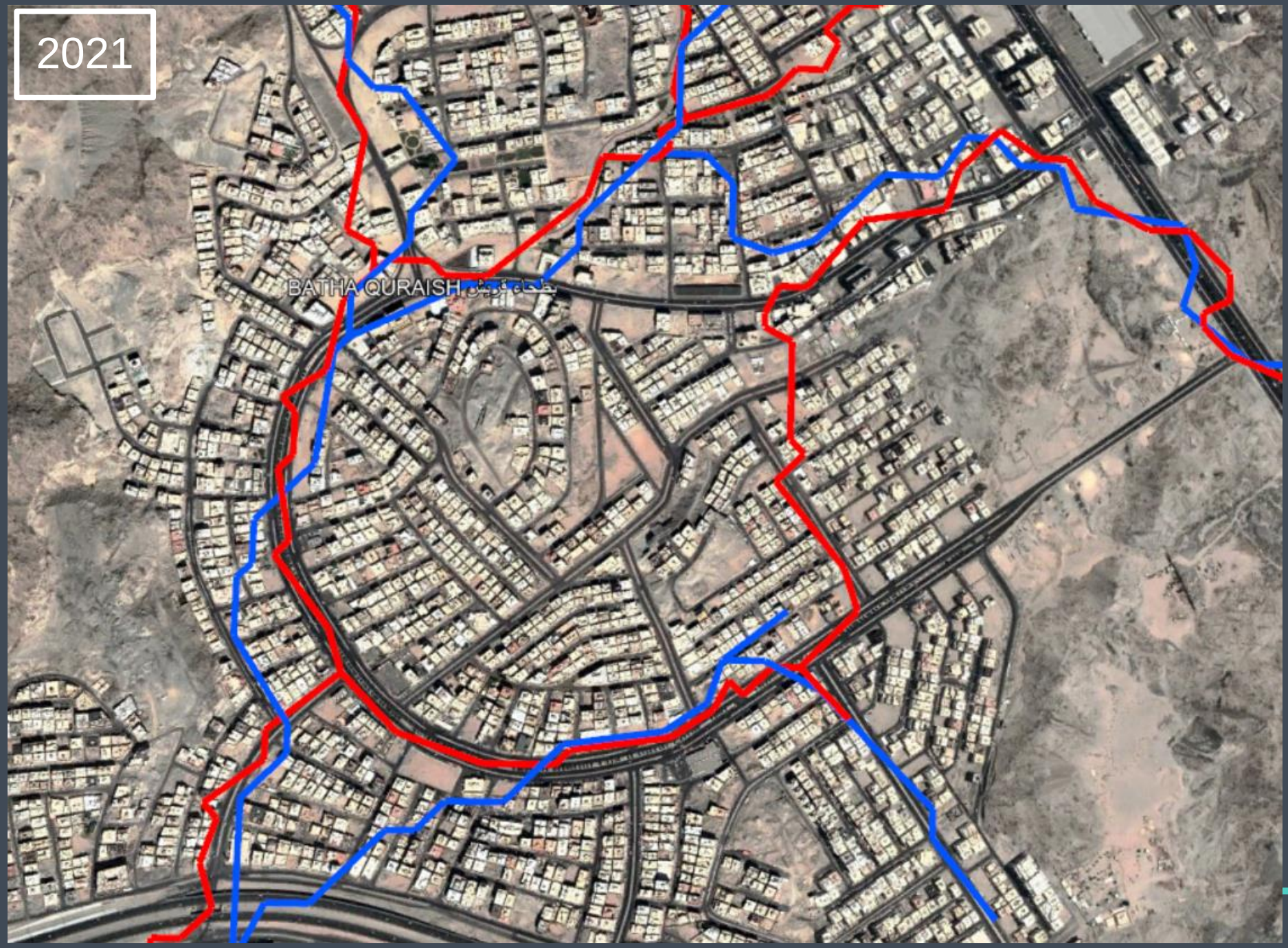
SRTM

Vs

Copernicus

Lat= 21°21'42.16"N

Long= 39°49'45.46"E



Mountain Area

SRTM

Vs

Copernicus

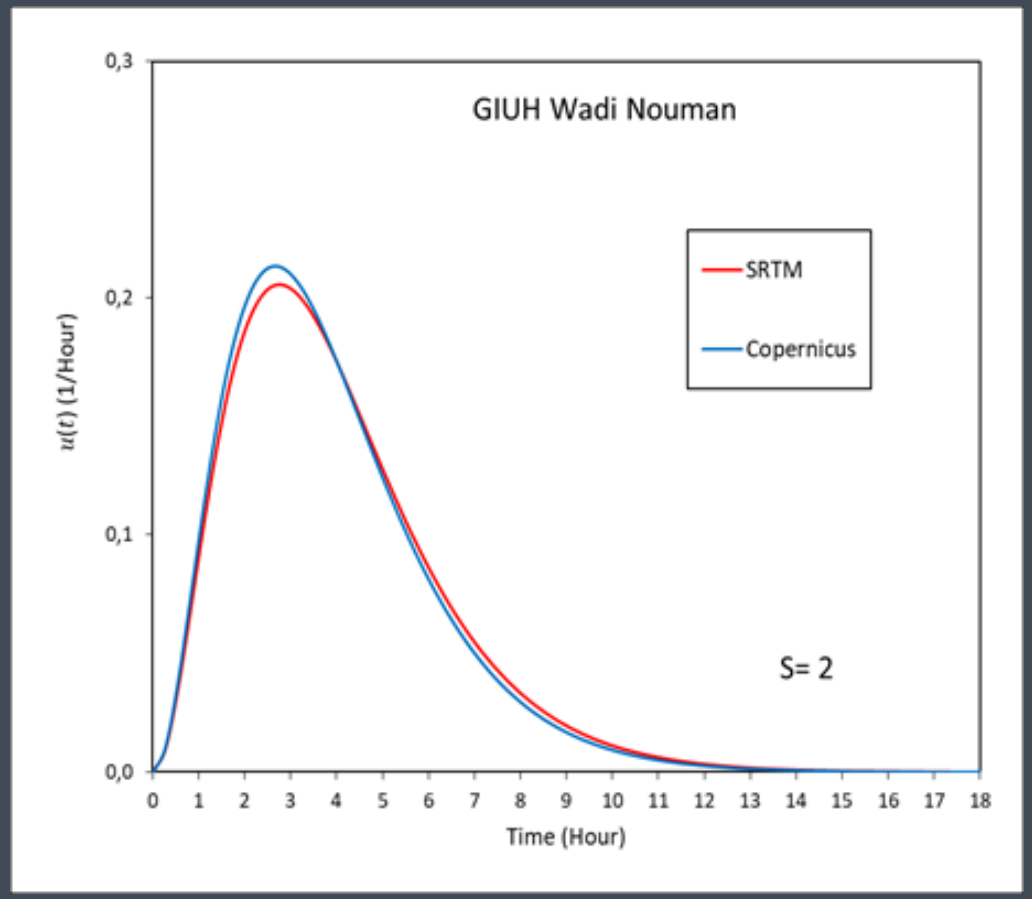
Lat= 21°30'56.38"N

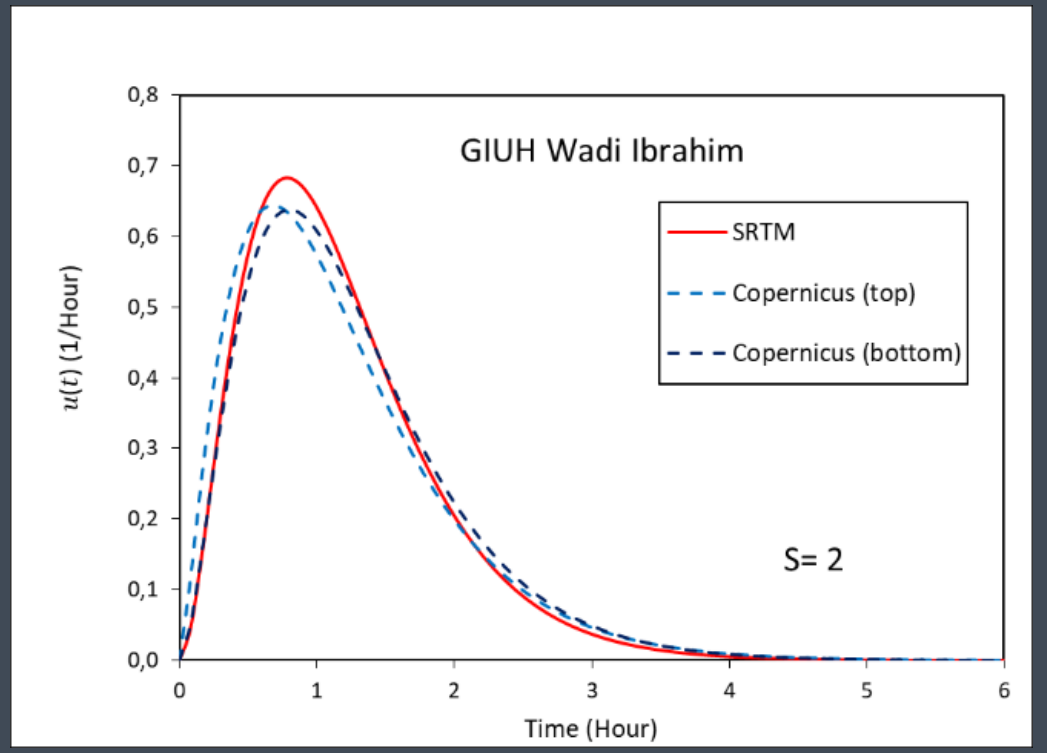
Long= 39°50'22.11"E

Source: Google earth

SRTM vs Copernicus – GIUH

GIUH Estimation





Each GIUH hydrograph has different shape, q_p and t_p due to different of Horton-Strahler parameters (R_B, R_L.and R_A L_Ω)

6

Conclusions

Conclusions – DEM Comparison

- Based on SAR data availability in Makkah City, the best results generated with lower errors compared to other pair images were obtained on December 10 and December 22, 2022.
- Despite having lower errors, the quality of DEM Sentinel-1 needs to be improved by using images within a suitable perpendicular baseline, short temporal baseline, and good atmospheric conditions for data acquisition.
- Based on the DEM elevation comparison, Copernicus and SRTM have the highest accuracy, with R = 0.9788939 m and 0.9765929 m, and the lowest RMSE 3.892.73 m and 4.232.96 m, respectively. Sentinel-1 and ALOS have threspectivelye lowest R2 = 0.9028909 and 0.9688227, and the highest RMSE was 65.31 m and 4.273.02 m,
- In wadi Ibrahim, it has been found that the wadi is divided into two sub-wadies based on Copernicus DEM.

Conclusions – Hydrological Stream Network

- Stream network and the morphometric parameters (Horton-Strahler ratios) of watershed vary for both DEM Copernicus and SRTM influence the shape of GIUH.
- Copernicus DEM has a higher q_p and lower t_p than SRTM on wadi Nouman. In wadi Ibrahim, Copernicus has lower q_p and higher t_p than SRTM.
- The stream network in the mountain area is almost similar for SRTM and Copernicus due to the dominant influence of the mountainous relief and relatively in-consequential influence of anthropogenic activities and DSM noise. In the urban area, the variation of the stream network is high due to differing DSM noise and significant anthropogenic activities such as urban redevelopment.
- Overall, the Copernicus DEM features the most reliable data quality compared to other open-source data and represents the most recent data.