**Tugas 2**

GD4105 Geodesi Fisik Lanjut

Rakhmat Senoaji, 15121051

# Topographic Models: A Performance Report

For this assignment, the global topographic surface models chosen are:

1. ETOPO2022
2. RTC ALOS PALSAR, and
3. ASTER GDEM V3, with
4. DEMNAS being the local model used

Before i do any analysis, the first thing i did was to check the data in `levelingexercise.dat`. The data is a collection of points with name, coordinate and orthometric height information. One question remain, "What resolution of model do i need?"

To solve that, i sorted the points by name, and calculate the great circle distance of the sorted points.

$$s = r * arccos((sin(\phi_i)sin(\phi_j)) + (cos(\phi_i)cos(\phi_j)cos(\Delta_\lambda ij))) \tag{1}$$

With:

- s being great circle distance
- r being earth's radius, in this case r = 6378137 m
- $\phi$ being one point's latitude
- $\lambda$ being one point's longitude
- i, j are two points with latitude and longitude

The results are shown in this figure. This is a histogram of the distances between two points of the data.

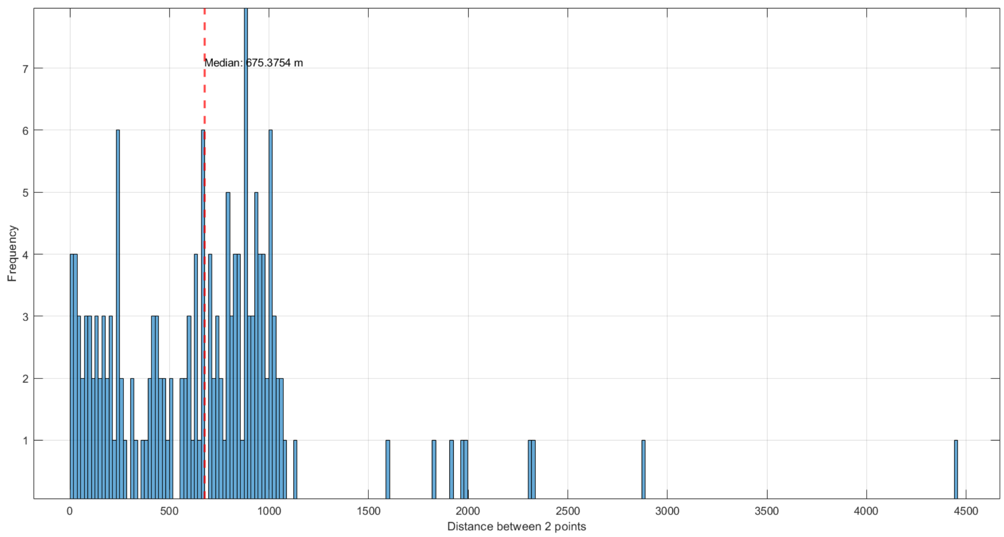


**Figure 1:** Histogram of distances between two points

From the histogram above, we can calculate the median of the distance is about 675 meters. So a Geoid model with a resolution better than 675 meters should achieve the desired granularity. 675 meters are worth about 22 arc-seconds.

After we determine the desired Topographic model Resolution, we can start by plotting the data into a 3D figure. Set the x axis to longitude, the y axis to latitude, and the orthometric height to z axis.

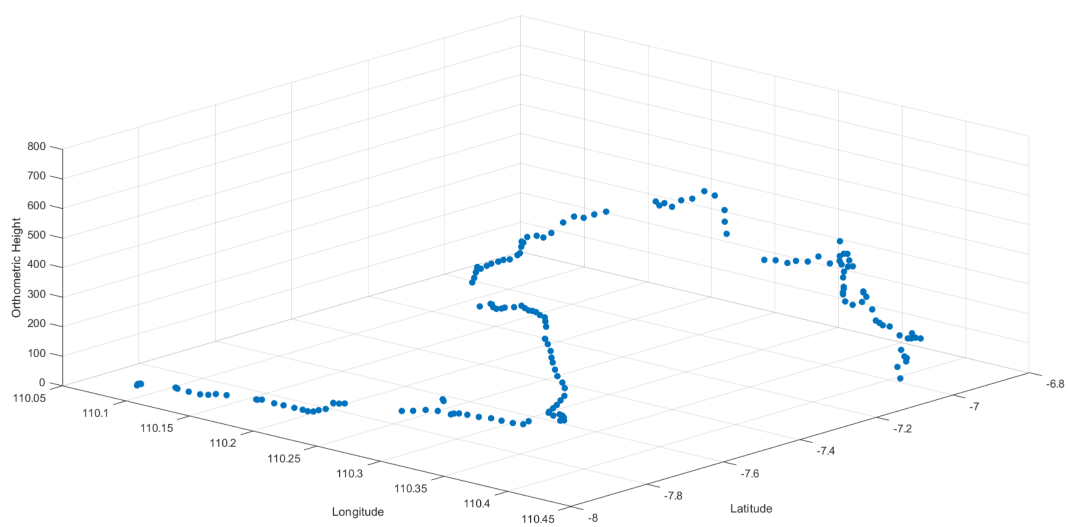


**Figure 2:** Sample Points drawn in 3D coordinates

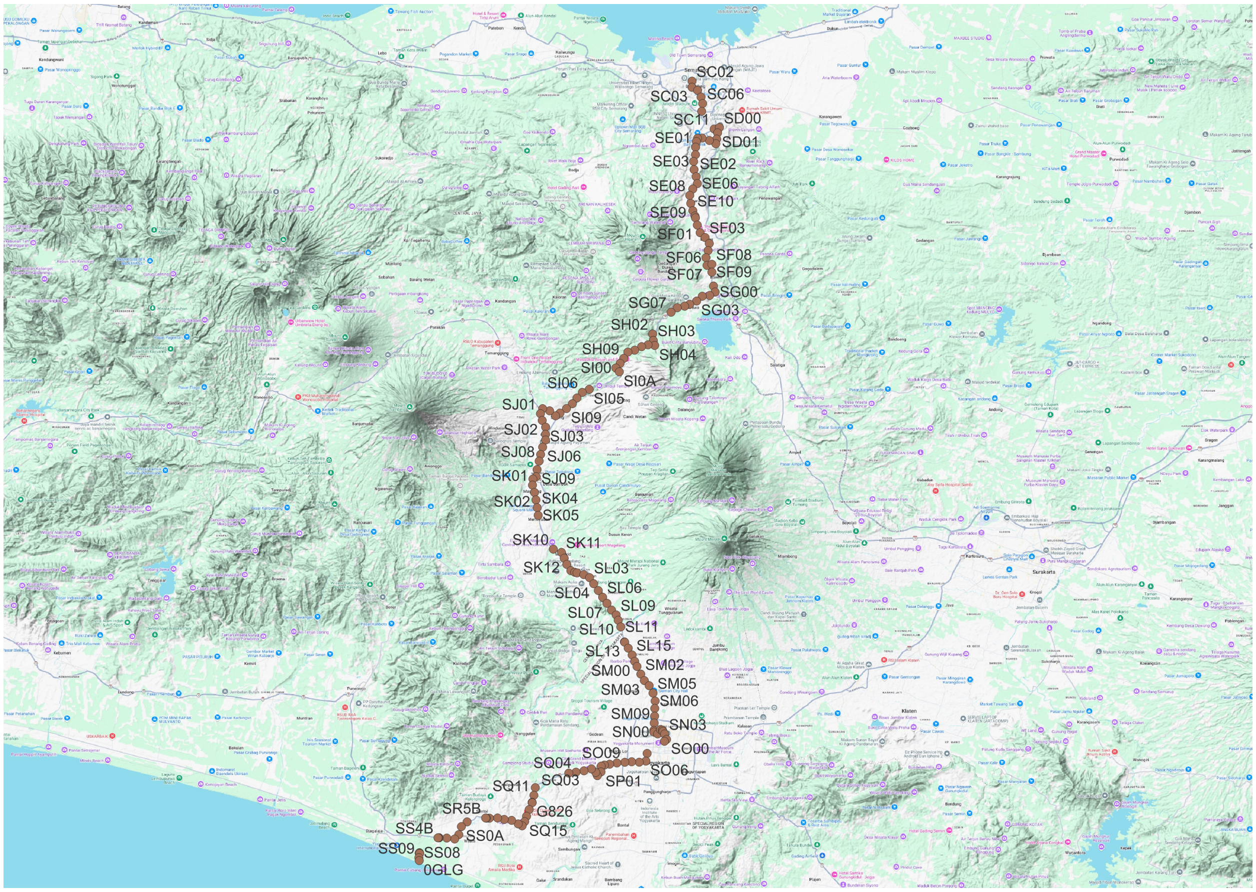


**Figure 3:** Points overlaid on a terrain basemap

The points start at a low elevation, then proceed to get their way up to about 700 meters of elevation, and began to descend to near sea level again. This is in line with the fact that if we overlay the points with a base map, they start at Semarang/Javanese North Coast, then to high plateaus in Magelang and Salatiga, and stops at the South Coast.

Now we can analyze all of the Models used:

- **ETOPO2022**

  The ETOPO data is gathered from https://www.ncei.noaa.gov/maps/grid-extract. The ETOPO model is a release of NOAA's "Earth TOPOgraphy" dataset. It is a full-coverage, seamless, gridded topographic and bathymetric bare-earth elevation dataset. The ETOPO dataset has a 15-arcsecond resolution. The ETOPO2022 model comes from many sources, including sea bathymetry, land topography, and ice sheet bed data, all of which come from global and regional datasets. For example:

  - GEBCO 2022 for ocean bathymetry.
  - Copernicus DEM for land topography.
  - NOAA Estuarine and Regional DEMs for coastal regions.

  Each data source contributes elevation data to specific regions, which are then compiled and stitched together into a seamless global grid of 288 individual 15*15 degree tiles. These tiles cover the Earth's surface at a resolution of 15 arc-seconds (about 450 meters).

**ETOPO2022 Quality Control**

ETOPO 2022 employs several layers of quality control, including **manual visual inspection** for artifacts and errors before inclusion, **Source Ranking** bathymetry sources by choosing the best ranked data in terms of quality, resolution, and age, and finally **validating** the data with ICESAT-2 dataset collected during the calendar year 2021. Any differences between the ICESat-2-derived ground elevation and the ETOPO grid cell are considered potential errors and analyzed for each input layer. (NOAA, 2022)

Unfortunately, The final vertical accuracy assessments for ETOPO 2022 are **still being compiled** with respect to ICESat-2 and is not available in the current version of ETOPO2022 User Guide document.

- **RTC ALOS PALSAR**

  The RTC (radiometrically terrain-corrected) ALOS PALSAR DEM is based on ALOS PALSAR satellite's Imagery data, and it used digital elevation models to perform geometric and radiometric correction in the SAR Imagery. The DEMs also provide the necessary elevation information to correct distortions caused by side-looking synthetic aperture radar (SAR) systems. The DEM sources used for terrain correction includes:

  - SRTM GL1
  - NED13 DEM
  - SRTM US1

  The RTC ALOS PALSAR is a 1-arcsecond (30 meters) resolution DEM data, that undergoes three main correction steps: **Pre-processing, terrain correction**, and **Post-processing**.

  **RTC ALOS PALSAR's Quality Control**

  The main quality control step is done at the terrain correction steps, where The SAR image is co-registered with a simulated SAR image derived from the DEM. The initial offset is calculated and refined to ensure the SAR image aligns with the terrain model. If matching fails, a "dead reckoning" approach is used to rely on geolocation data. Once the images are co-registered, a normalization area image is generated. The terrain correction results in a radiometrically calibrated multilooked image with $\gamma^0$ power scale values. The ratio between the pixel area of the uncorrected and the corrected images is determined and stored in an image.

- **ASTER GDEM V3**

  The ASTER dataset was created using stereo images from the ASTER instrument on NASA's Terra spacecraft, which provides global digital elevation data in a 1-arcsecond (30m) resolution. The ASTER GDEM V3 dataset is built from 1,880,306 Level-1A stereo scenes acquired between March 1, 2000, and November 30, 2013. To create a consistent elevation model, multiple scenes are stacked for each location, with cloud-masked scenes and unmasked scenes combined.

  **ASTER GDEM V3 Quality Control**

  Existing DEMs like SRTM1 V3, Alaska DEM, Canadian Digital Elevation Dataset (CDED), and Global Multi-resolution Terrain Elevation Data (GMTED2010) are used to replace anomalies and fill data gaps. These reference DEMs provide high-quality baseline elevation data, ensuring that the ASTER GDEM remains nearly void-free, except for areas like Greenland and Antarctica.

- **DEMNAS** The DEMNAS data is a DEM model developed by the Indonesian Body of Geospatial Information (BIG). The model used and blended several data sources, including TerraSAR-X, IFSAR, and PALSAR data, which was assimilated with mass points from stereoplotting process. The assimilation process considers the height difference between the above-ground elevation of the mass point and the surface elevation of the DSM to produce a corrected DTM (Digital Terrain Model)To correct them, they used many trusted mass point obtained from previous measurements. The DEMNAS has a very granular 8.25m resolution.

### Model Comparation

Now, we can compare the models. First things first, the given data in `levelingexercise.dat` is used as reference to be compared with all the data, because the data is assumed to be taken with leveling measurement constrained to the tide gauge observations in Yogyakarta, which means that the error is assumed to be low. Firstly, let's examine the difference between all of the data across all the points.

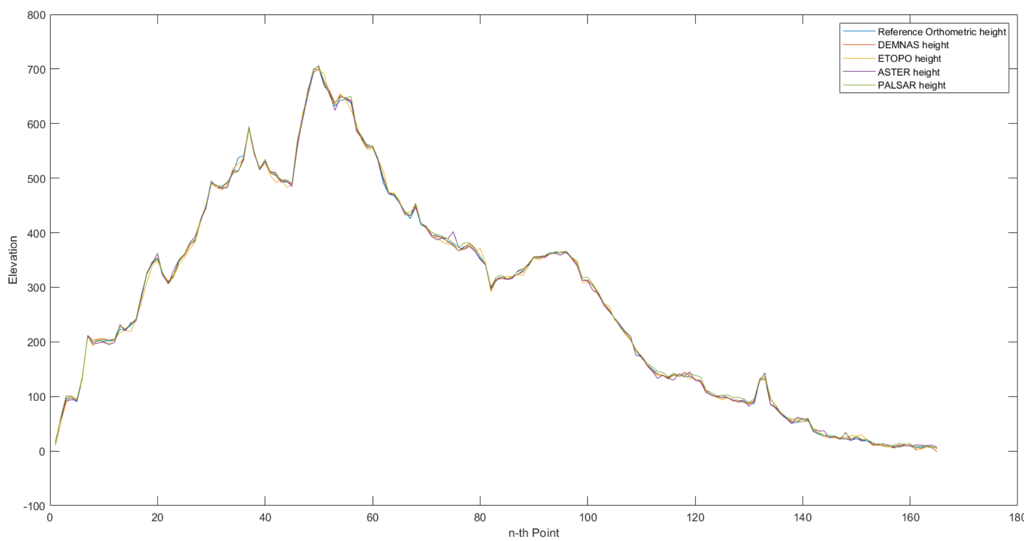


**Figure 4:** Plot of points from every dataset

From the figure above, we can visually quantify that the data points generally agree with each other, only deviating slightly in several spots (about 25m in point 35, for example). We need to analyze the difference between the reference height and the models to reveal more information, because visual inspection does not yield many insights.

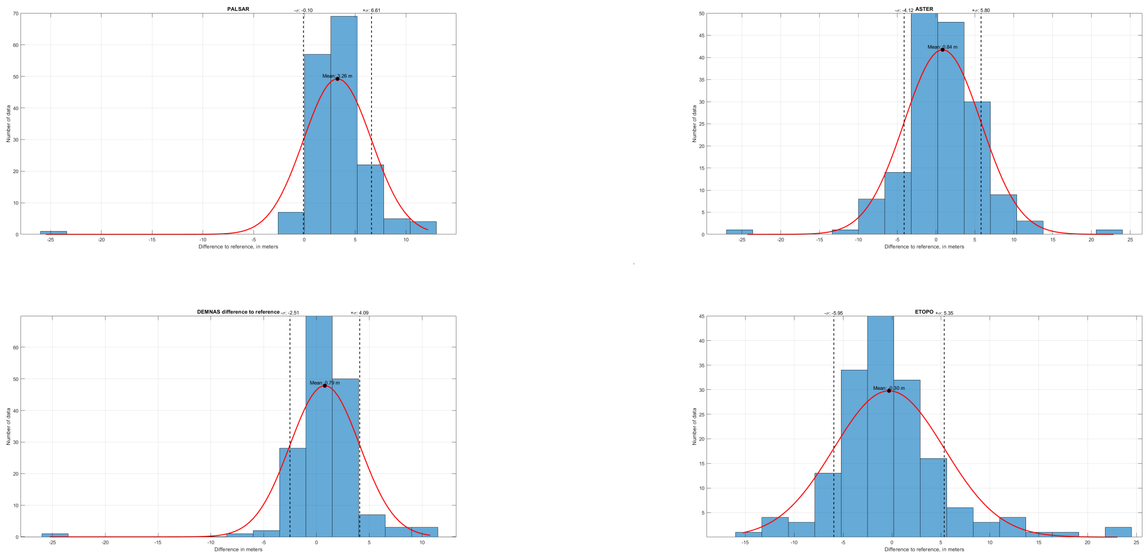


**Figure 5:** Comparative differences in elevation models: PALSAR, ASTER, DEMNAS, and ETOPO

From the figures above, we can see clearly about the behaviours of each models. First of all, all of the models' differences to the reference data is in the shape of a normal curve (although shifted, with PALSAR data being the most distant to 0). So, we can say that the 3 of the data does not have enough evidence to contain errors other than random errors. On the other hand, the PALSAR data shifted the mean error 3 meters to the right. That means that the elevation from PALSAR data in The Central Java region tend to be shifted 3 meters up. This could be due to several factors, such as the DEM reference used by PALSAR being inaccurate in this region (SRTM GL1).

In the figure below, the error data of every model is overlayed in one graph to highlight the differences even more.

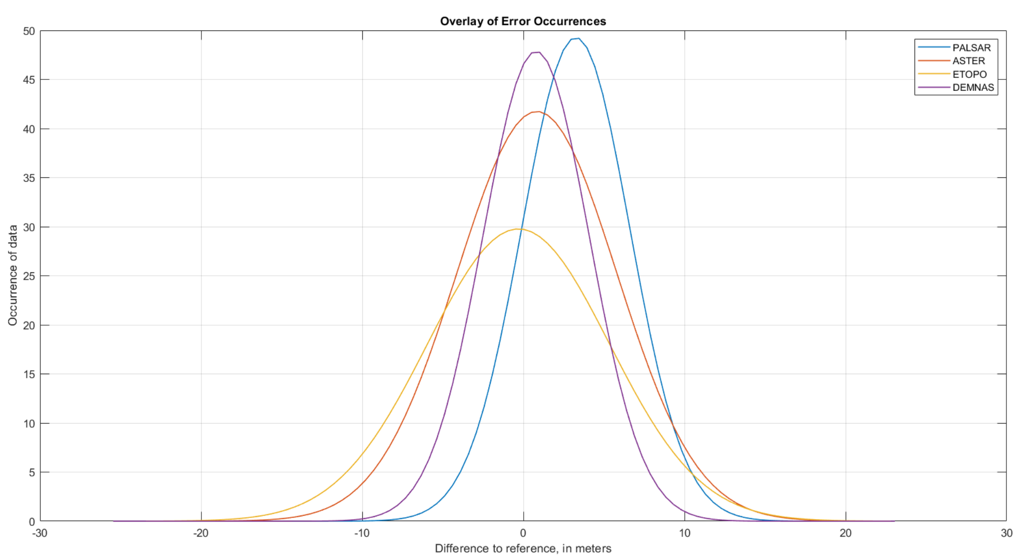


**Figure 6:** Error overlay of each models

Analyzing the graph, we can infer the characteristics of every models:

- **PALSAR** The PALSAR data is the most interesting of them all, because the data is shifted about 3 meters from the reference either from processing or correction systematic errors, albeit with a low standard deviation (3.35m). Therefore, PALSAR data is not recommended to be used in the Central Java area because of other models being more accurate.

- **ASTER GDEM V3** The ASTER GDEM V3 data is quite good to be used in Central Java region, because the data seems to be centralized near 0 (0.84m) but with a high standard deviation (4.96m). Other models need to be considered.

- **DEMNAS** The DEMNAS data is very good to be used in Central Java area, it is centralized very near 0 (0.79m) with very low standard deviation (3.3m). This is due to the DEMNAS data being constrained with field data that we have done in Indonesia.

- **ETOPO2022** Similar to ASTER GDEM V3, the ETOPO2022 data is also a good contender to use in Central Java area. It is centralized near 0 (-0.3m) but with high standard deviation (5.05m). Other models need to be considered.