Suitability Assessment of SRTM and ASTER GDEM2 Digital Elevation Model for Terrain Analysis in Aba North: A Case Study of Abia state polytechnic Aba.

Abstract

Accurate geospatial data is fundernental to reliable decision making for sustainable physical development on earth surface. Open-source Digital Elevation Models (DEMs) are imperative to many earths' surface process analysis therefore it is necessary to subject them to accuracy assessment to evaluate their suitability for different geographical applications. In this study, the elevation quality of DEMs acquired by Surface Radar Topographic Mission of 30m resolution (SRTM-30) and Advanced Spaceborne Thermal Emission Radiometer-Global Digital Elevation Model version2 (ASTER GDEM2) has been evaluated using ground control point captured with digital level and Differential Global Positioning System (DGPS). Two main approaches used to compare the elevation products are determination of the accuracy of the elevation values of the products using 96 ground elevation point (absolute accuracy) and determination of the accuracy of terrain derivatives of the products (relative accuracy). Statistics used to assess absolute accuracy are mean error, root mean square error, correlation coefficient, difference in maximum height, and difference in minimum height. The relative accuracies were assessed by considering similarities between terrain derivatives generated from the DEMS and their equivalence from ground reference. Results showed that ASTER-GDEM2 has a lower Root Mean Square Error (RMSE = 3. 10m) than SRTM-30m (RMSE = 3.69 m). Further investigation in terms of relative accuracy also revealed that ASTER GDEM2 performed better than SRTM-30 for the study area. Both datasets featured a much better absolute vertical accuracies than the absolute vertical accuracies of 17m (ASTER GDEM2) and 16m (SRTM-30) published in the specification. Although the results of this study may be site-specific, it is an important information that users of the DEMs within Aba north should be aware of, and must be considered into decisions regarding practical applications of these Spatial products. It is also important that the results be considered for the improvement of the next open source GDEM version**.**

KEY WODS; SRTM, ASTER GDEM, Terrain, Elevation.

1.0Introduction

DEM is an array representation of squared cells (pixels) with an elevation value associated to each pixel. It is a two-dimensional array of numbers that represents the spatial distribution of elevations on a regular grid. DEMs are used as elevation data sources in various geospatial studies and applications, such as topography, geomorphology, urban studies, hydrology and several applications that require surface height information [1, 3]). DEMs can be generated using several methods, with varying degrees of accuracy. Traditionally, they have been derived from topographic maps, global positioning system (GPS) measurements, photogrammetry techniques, using auto level, total station etc. The availability of Open source DEMs like ASTER-GDEM and SRTM-DEM has a great impact on scientific researches, as they provide moderate quality dataset at a lower expense [3]. Use of satellite images for DEM production have a tremendous advantage over conventional methods in that DEMs over large and inaccessible areas can nowadays be assessed at a reduces cost and time. In recent times Interferometric Synthetic Aperture Radar (InSAR) have become popular in extracting elevation data. Radars have two main advantages over optical techniques are: (1) Image capture is independent of natural illumination and therefore can be taken at night. (2) Observations are not affected by cloud cover since the atmospheric absorption at typical radar wavelengths is very low [5, 6]. Shuttle Radar Topographic Mission (SRTM) and Advanced spaceborne thermal emission and reflection adopted this technology.

SRTM and ASTER-derived DEMs are among the most frequently used datasets for geospatial analysis due to their near-global coverage [7]. The Shuttle Radar Topography Mission also known as the mission of the Endeavour spacecraft acquired radar datasets for 11 days between February 11 and 22, 2000. [8] From the radar data sets, a digital elevation model (DEM) with coverage between about 60^0 north of latitude and 56^0 south of latitude was generated [9]. It produced topographic dataset on 90-meter horizontal spatial resolution and an absolute horizontal and vertical accuracies are given as equal to 20 meters and 16 respectively

The mission of the SRTM was conducted in cooperation between the National Aeronautics and Space Administration (NASA) of the United States, the German Aerospace Center, the Italian Space Agency, and the National Geospatial-Intelligence Agency (NGA) and covered about 80% of the earth surface [10, 11]. The 3arc second SRTM was made available to the public while the 1 arc second version which was only made available for USA has been released to the public in 2014 [12]. The original SRTM elevations were calculated relative to the WGS84 ellipsoid and then the EGM96 geoid separation values were added to convert to heights relative to the geoid for all the released products.

On 29 June 2009, ASTER Global Digital Elevation Model (GDEM) was produced through combined operation between NASA and Japan's Ministry of Economy, Trade and Industry (METI). It is the most complete mapping of the earth ever made, covering 99% of its surface. The GDEM covers the earth from 83 degrees North to 83 degrees South (surpassing SRTM's coverage of 56 °S to 60°N). Further modification of GDEM was made in 2011 (GDEM version2) [13]. This modification was made to include increased horizontal and vertical accuracy, better horizontal resolution, reduced presence of artifacts, and more realistic values over water bodies

Where local topographical data is unavailable, incomplete or outdated, Open source DEMs can be the main source of information. Digital Elevation Models (DEMs) provide data for interpretation of the Earth's surface and are generally considered to be dataset for wide range of geospatial analysis [14]. People are interested in the place where they live, Geologists study the earth layers, geo-morphologists are interested in its shape, Architects and Civil engineers design and construct buildings on it, and topographic analyst are concerned with measuring and describing its surface and presenting it in different ways. These geo-analysts wish the surface of the terrain to be represented conveniently and with certain level of accuracy. One of the limitations of these global DEMS is presence of offsets where canopy exists [15]. Therefore, these datasets need to be subjected to quality assurance before use for a particular geographical application. The RMSE for DEMs is calculated by comparing the DEM with elevation of points that reflect the "most probable" elevations at those locations obtained by more reliable methods. It has been widely used by researchers in different part of the world to access the accuracy of DEMs. In [16], Santillana and Makinano used RMSE as a standard to compare the accuracies of ALOS, ASTER, and SRTM DEMs in Northern Philippine. Shaopeng used RMSE as a yard-stick to compare the accuracy of ASTER-DEM and

SRTM in Northen China [17]. Also, in [18] Arun, Katiyar and Vishnu used mean error (ME) and root mean square error as standard statistical parameters to evaluate the accuracies of SRTM, ASTER and Cartosat-1.

1.1 Objectives of this study

The objectives of this study are:

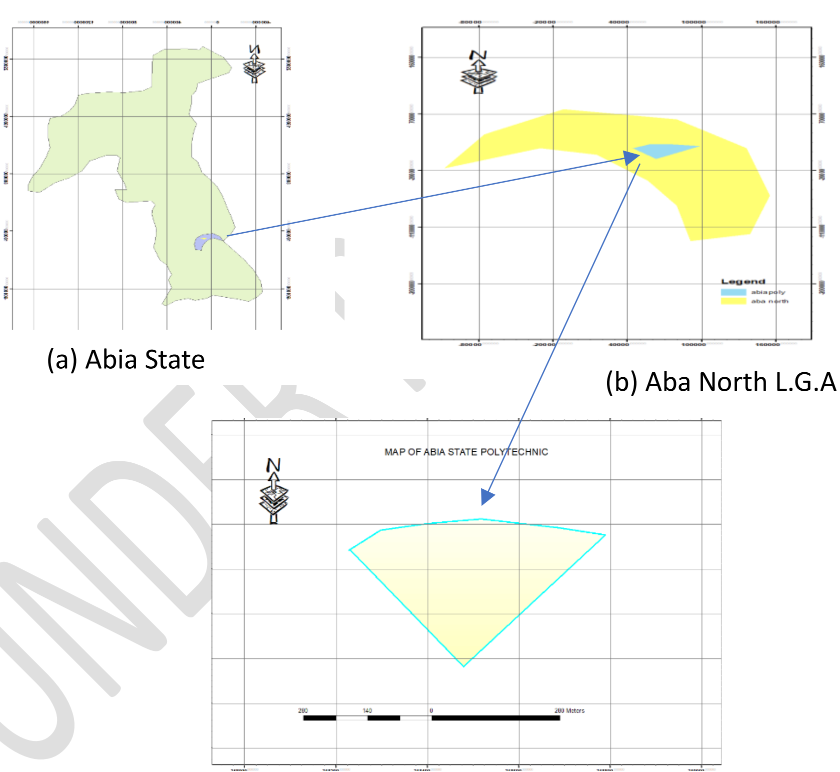
To determining the accuracy of the elevation values of the products (absolute accuracy)

To determining the accuracy of terrain derivatives of the products (relative accuracy)

To determine the open-source DEM most suitable for terrain analysis within the study area base on the result

1.2 Description of the study area

The study area is Abia State Polytechnic Aba. It measures approximately 150, 000 square meters and is located in Aba North L.G.A. of Abia State – Nigeria, West Africa. Geographically, the study area is located between latitude 5^0 06'N and 5°07'N and between longitude 7^0 21'E and 7° 23. Figure1 is the location map'



(c) Abia State Polytechnic

Figure 1 Location map

2.0 Methodology

SRTM DEM of 1-arcsecond resolution (30m resolution) which is being made publicly available through, the United States Geological Survey's EarthExplorer site was as used for this study. The elevation raster data was downloaded from (http://earthexplorer.usgs.gov). The ASTER Global Digital Elevation model used in this study is freely available from the website of Japan Space Agency since June 2009 and was downloaded from (http://gdem.ersdac.jspacesystems). Elevation values of ground positions should be in the same vertical datum with the open source DEMs before comparison is said to be faithful. To achieve this both elevation raster datasets of the study area were added to ArcGIS 10.5 window and the study area was masked out. Progressively, elevation of the same point position was extracted from both SRTM and ASTER. Precaution was taken to ensure that the location considered was of considerable similar elevation values in the two raster datasets. The same point position was identified on the ground and use as benchmark. Its average elevation value from the two datasets was used as reference elevation of the benchmark for the ground levelling positions covering the study area and DGPS was used to coordinate the grid nodes. The DEMs and GPS data which were originally in WGS84 horizontal datum were projected to UTM ZONE 32 Horizontal platform. 96 randomly selected sample of the ground positions covering the study area were selected and overlaid on the two DEMs and their elevation values were extracted and compared with their ground equivalence. These ground data were randomly selected to avoid bias in the samples selected. Metrics used for comparison are; mean error, root mean square error, correlation coefficient, difference in maximum height, difference in minimum height (see table1). The entire ground reference data was imported into ArcGIS10.5 window and converted to raster for comparison with the open-source DEMS. Progressively, these raster files were respectively converted to point data and exported to Sufer11 window where other spatial models were produced in different cartographic format for relative comparison (see figure 2 to 5).

3.0 Result and discussion.

3.1 Absolute accuracy determination of DEMs

One of the standards by which Accuracy of a map is determined is Root-Mean-Square-Error (RMSE). It measures the difference between the estimates from the satellite data and the true ground reference obtained by reliable means. These individual point differences are called residuals, and the RMSE serves to aggregate them into a single measure of predictive power. It is a single quantity characterizing the error surface, and mean error (ME) reflects the bias of the surface. The ME tells us whether a set of measurements consistently underestimate (negative ME) or overestimate (positive ME) the true value. The first analysis was made to statistically investigate the level of agreement between SRTM, and ASTER pixel values with the corresponding ground reference (Absolute accuracy) using RMSE and ME as standards. This analysis was carried out using 96 well distributed ground elevation points within the study area. Correlation analysis was also performed to assess the level of correlation between the estimates from DEMs and truth from ground reference.

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Table1 Absolute accuracy metrics derived from the 96 checkpoints

	SRTM	ASTER
ME	1.47	- 0.51
RMSE	3.69	3.08
R^2	0.95	0.99
ΔH_{max}	2.60	-3.00
ΔH_{min}	- 2.00	0.50

$ME = \frac{1}{n} \sum_{i=1}^{n}(z' - z)$. The Mean error

RMSE $= \sqrt{\frac{1}{n} \sum_{i=1}^{n}(z' - z)^2}$. The root mean square error

where Z = observed values of the height.

Z' = modeled values of the height;

R^2 = Coefficient of correlation.

$\Delta H_{max..}$ = Maximum height in satellite DEM – maximum height in ground reference.

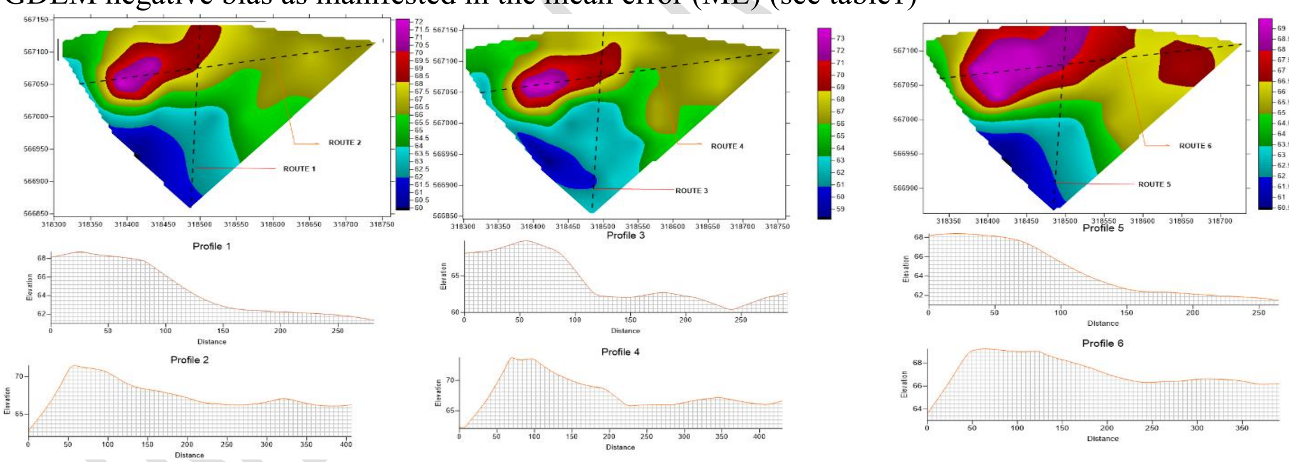
ΔH_{min} = Minimum height in DEM – minimum height in ground reference

From the above analysis it is revealed that ASTER-GDEM2 produced a Lower RMSE of 3.08m with ME of 0.5m and R^2 of 0.99 while that of SRTM is comparatively higher with values of RMSE, ME and R^2 recording 3.69m, -1.47m and 0.95 respectively as shown in table1

3.2 Relative accuracy comparison.

3.2.1 Comparison of Profiles

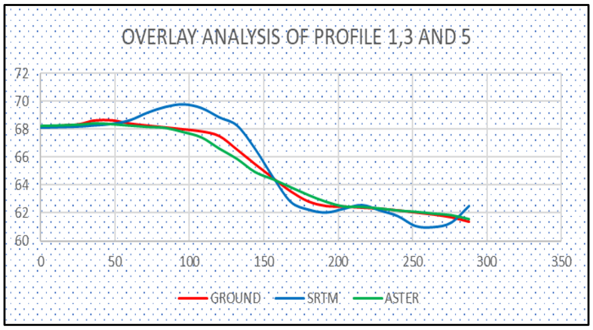
The variation of heights in satellite DEMs is seen by considering profiles along two sections as shown in figure2a, figure2b and figure2c. For further investigation, profiles from the DEM were overlaid on their corresponding reference profile to detect the differences visually as shown in figure3a. and 3b. It can be seen that there is a high variation of SRTM based profiles from the truth compared to ASTER-GDEM2. The variations from SRTM are positive bias while that of ASTER-GDEM negative bias as manifested in the mean error (ME) (see table1)



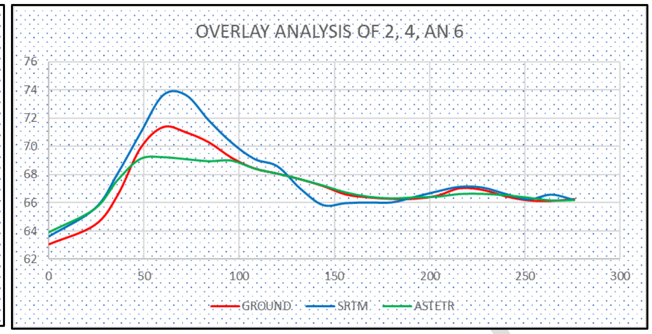
(a) (b) (c)

Figure2 comparison of profiles from DEMS

Column (a) is ground data DEM and profile of two sections on the DEM, Column (b) is SRTM-DEM and profiles of two sections on the DEM and Column (c) is ASTER DEM and profiles of two sections on the DEM.



(a)



(b)

Figure3 Overlay analysis of the DEMs profile with that of ground reference along two sections in the study area.

3.3.2 **2-D, 3-D Analysis**

This analysis was made to compare the contour pattern and undulations between the DEMs and reference data. Contour map and 3-D surface model were generated from the ground reference data fig4a and compare with that of SRTM fig4b and ASTER-GDEM2 fig4c. These investigations show that SRTM revealed undulations better than ASTER (see point A, B, C and E) in figure4a through 4c. However, a cursory view of the spatial models revealed that contour pattern generated from ASTER-DEM2 is a better estimate of the truth when compared with SRTM.

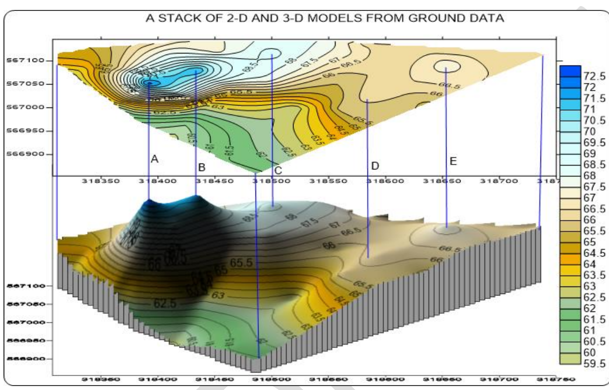


Figure 4a. 2-D and 3-D models from ground data

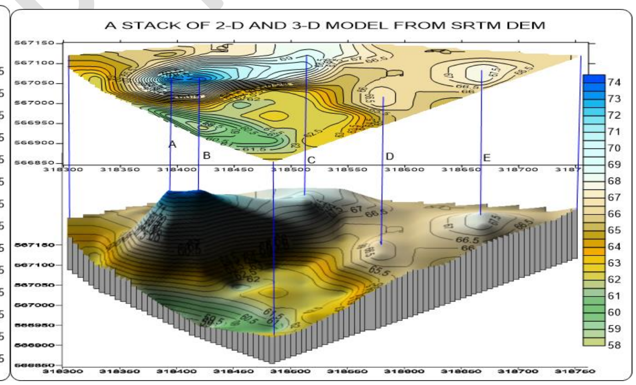


Figure 4b. 2-D and 3-D models from SRTM

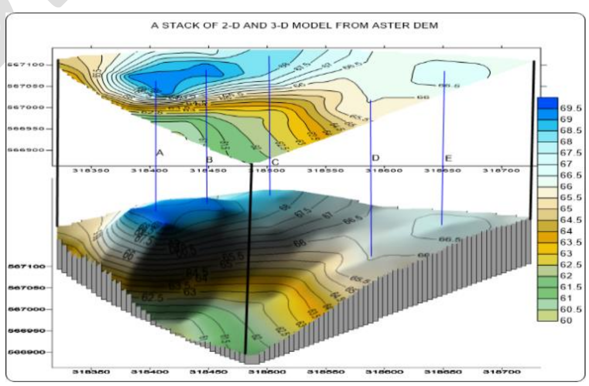


Figure 4c. 2-D and 3-D models from ASTER

3.2.3 Surface Flow Analysis

The elevation of an area, controls the hydrological character of the region. In order to estimate relief-related parameters in shaping the surface and controlling the processes that operate, it is necessary to have good quality, high-resolution elevation data. Surface flow analysis is crucial for surface designing to reduce flooding and erosion also for drainage construction. flow direction models showing surface flow pattern on the true and estimated surfaces were generated and compared. A cursory look at the flow vectors revealed that except on the highest relief region (see figure5) surface flow characteristics from ASTER-GDEM2 (figure5c) is a better approximate of the truth (figure5a) compared to SRTM vector model (figure5b)

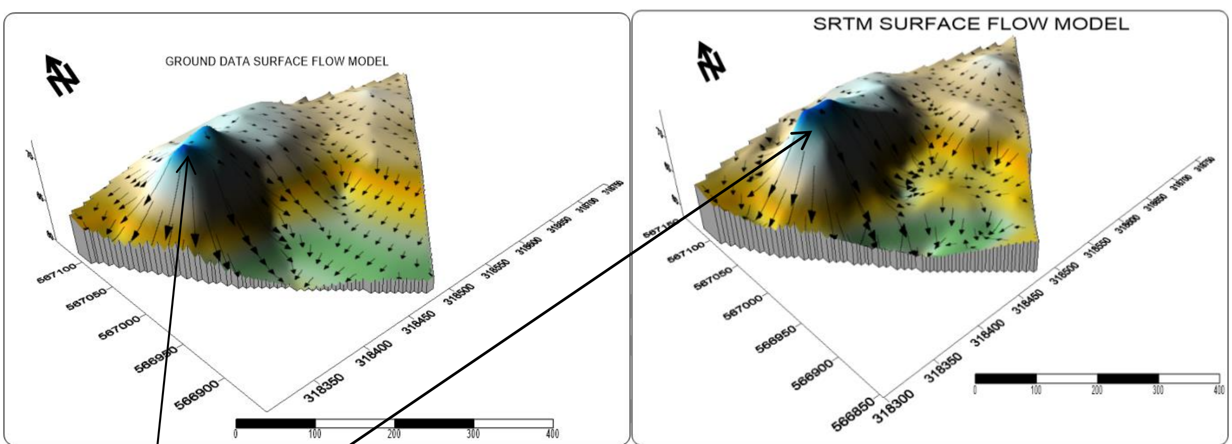


Figure5a Ground data surface flow models

Figure5b SRTM based surface flow models

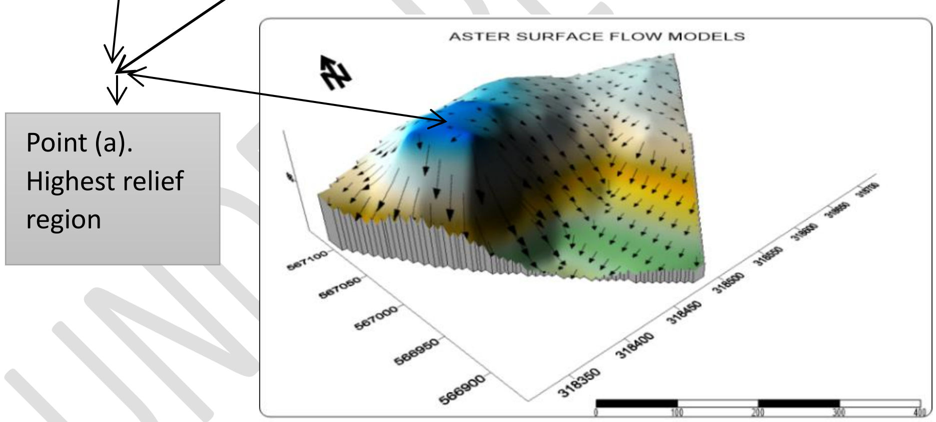


Figure5c ASTER GDEM2 based surface flow models

4.0 Conclusion

In this study, two near-global DEMs – SRTM-30 and ASTER GDEM2 has ben compared using DEM Produced by ground data as reference in Aba north using Abia state polytechnic as a case study. The reference DEM data used was captured using Promark DGPS and digital kevel. Root mean square error, mean error, correlation coefficient are the statistical metrics used for absolute comparison while, profiles, 2-D model (contour pattern), 3-D model, and flow vectors are derived land components used for relative comparison. Our vertical accuracy assessment using 96 GCPs shows that ASTER-GDEM2 was more accurate in depicting true ground elevations as it has the lower mean error, RMSE and higher correlation coefficient with values of -0.51, 3.08 and 0.99 respectively while SRTM recorded values of 1.47 , 3.69 and 0.95 respectively for ME, RMSE, and R^2. The study further revealed that ASTER-GDEM2 was better in depicting the terrain derivatives. However, SRTM raster estimated high undulations better than ASTER-GDEM. Analysis conducted revealed that SRTM overestimated the ground elevation (positive biased) which may be partly due to recorded reflections from canopies. On the other hand, ASTER-GDEM underestimated ground elevation (negative biased). Though these findings may be site specific but can be considered an important information that users of the DEMs within Aba north should be aware of, and must be considered into decisions regarding applications of these Spatial products.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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