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Processing Matters: 3D Mesh Morphology

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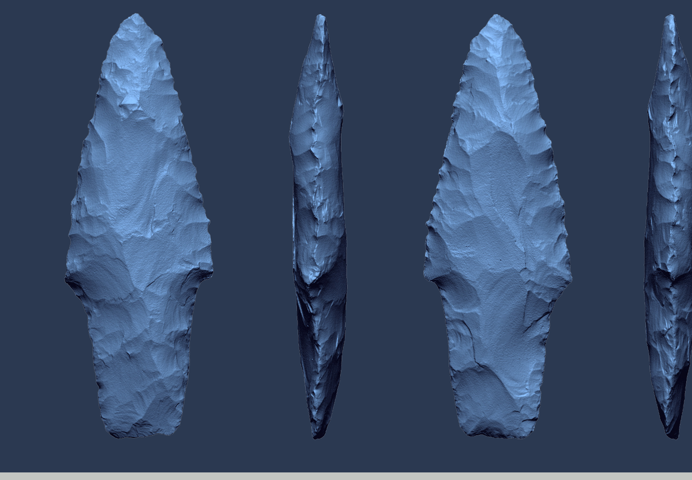

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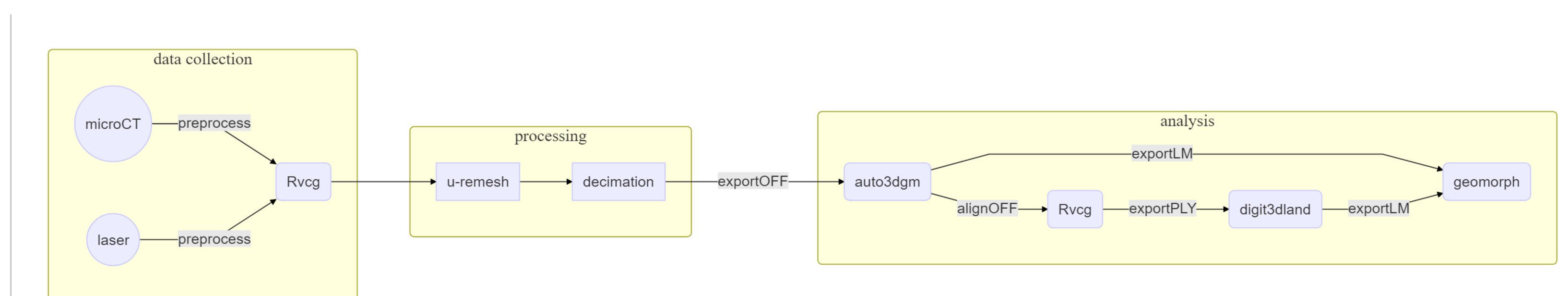
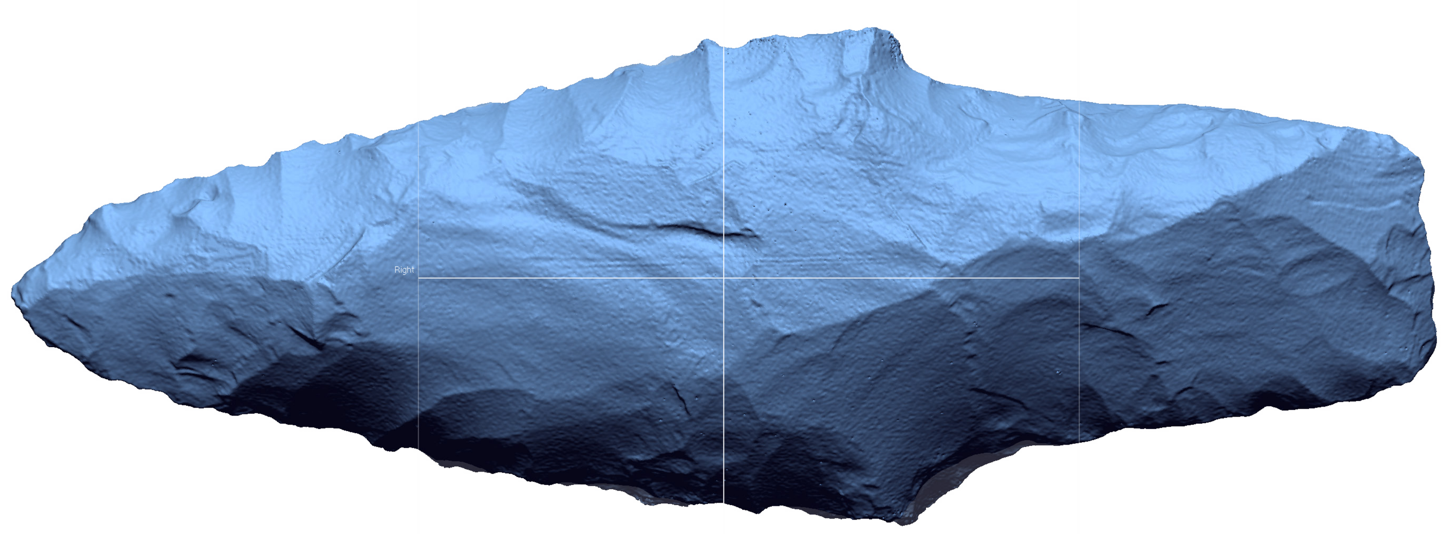
Abstract

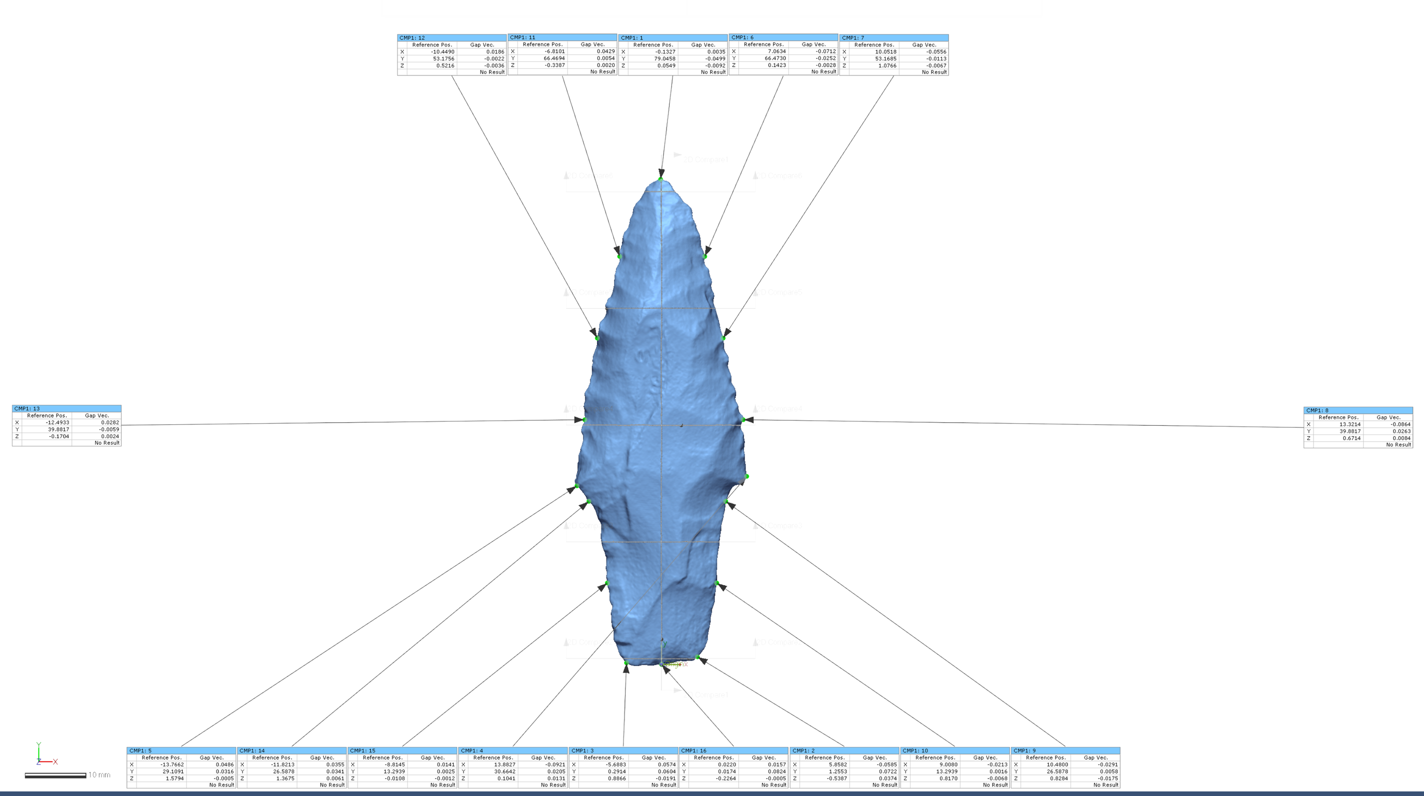
Substantive advancements have been made toward automating the application of landmarks and semilandmarks. These approaches can aid in expediting the landmarking process, while simultaneously reducing landmarking errors and investigator bias. This study enlists a template-based approach to quantify deviations in mesh processing outputs using a Pontchartrain dart point from the collections of the National Forests and Grasslands in Texas, which was scanned and processed at multiple resolutions using microCT and laser scanners. Following data collection and output, meshes were processed using an automated and replicable workflow. A batch processing protocol was developed in Geomagic Design X and Control X to facilitate exploratory comparisons of the processed meshes, which indicated that the greatest changes to the meshes occurred along the lateral margins of the dart point. Results of the geometric morphometric study evince implications for processed meshes curated in digital repositories. Investigators that endeavour to incorporate curated meshes should begin with the unprocessed data, enlist uniform processing protocols across the sample, and comprehend the many vagaries of 3D data collection and processing across different modalities.

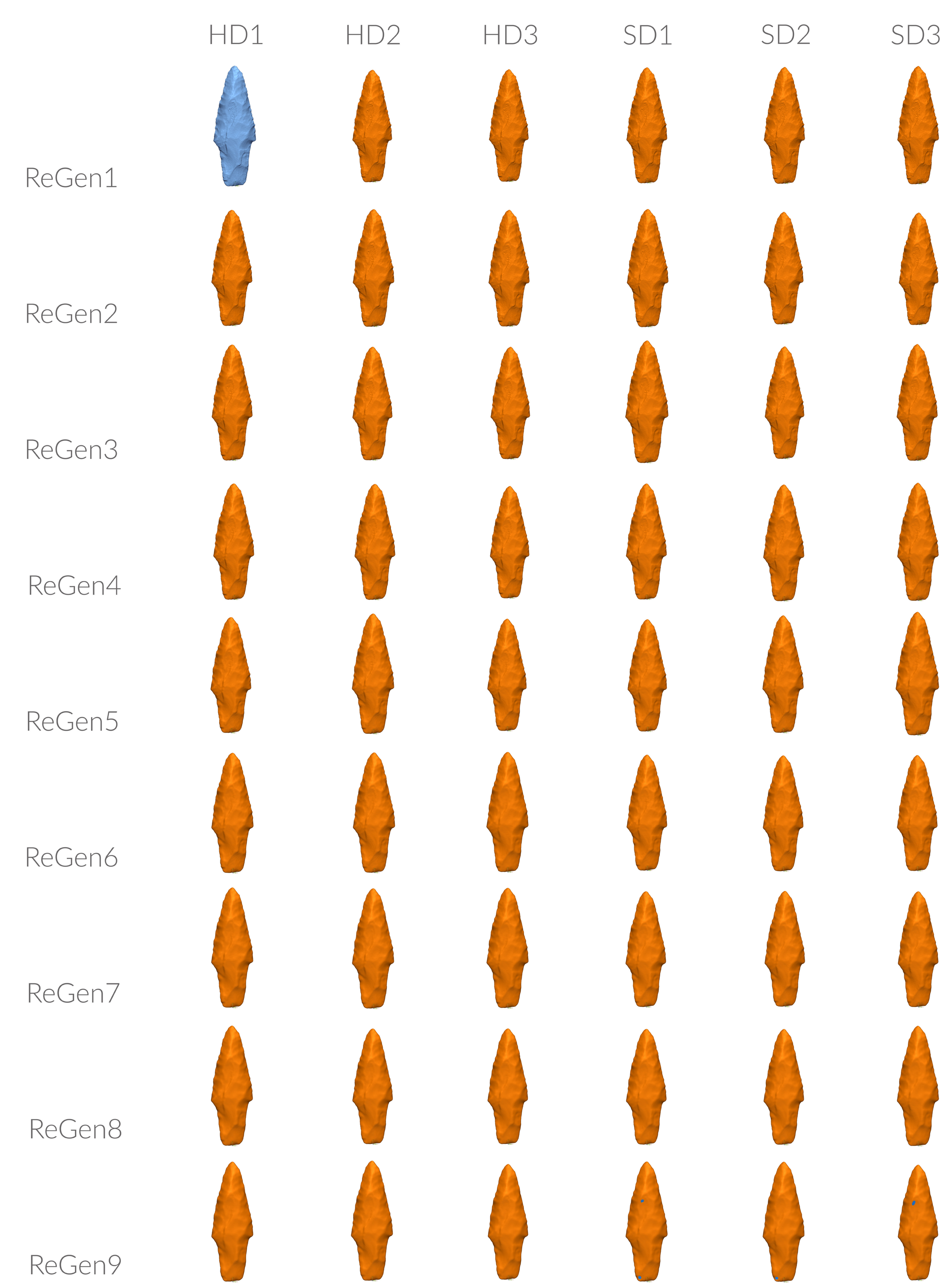
This endeavour is focused upon the morphological variation introduced for a single artefact over six scan resolutions and nine Regen settings using the NextEngineHD scanner. Six 3D scans were collected at six resolutions; three using the HD settings in ScanStudio HD PRO (HD1-3), and three using the HD settings in ScanStudio HD (SD1-3). Scan data were collected by scanning the same specimen using the identical placement for each scan to ensure uniform data. The 360-degree scans were generated in three positions: one with the Pontchartrain point upright (vertical--point up, base down), one oriented on its lateral edges, and one of the edge profile. Following placement of the point on the NextEngine stage, it was scanned six times, at six different resolutions prior to moving it to the second position, and again before to moving it to the third position.

Each scan was saved twice. Once as a reference and backup that was uploaded to the Open Science Framework as an unprocessed mesh. The other was trimmed, aligned, fused, and polished to produce the nine meshes needed for the analysis, which were then uploaded to the Open Science Framework as an stl file. In total, 54 meshes were generated from six scans, each processed at nine resolutions for the same Pontchartrain dart point with the NextEngineHD. Three microCT scans were recently collected with a Bruker SkyScan that will be added to this analysis in a subsequent iteration.







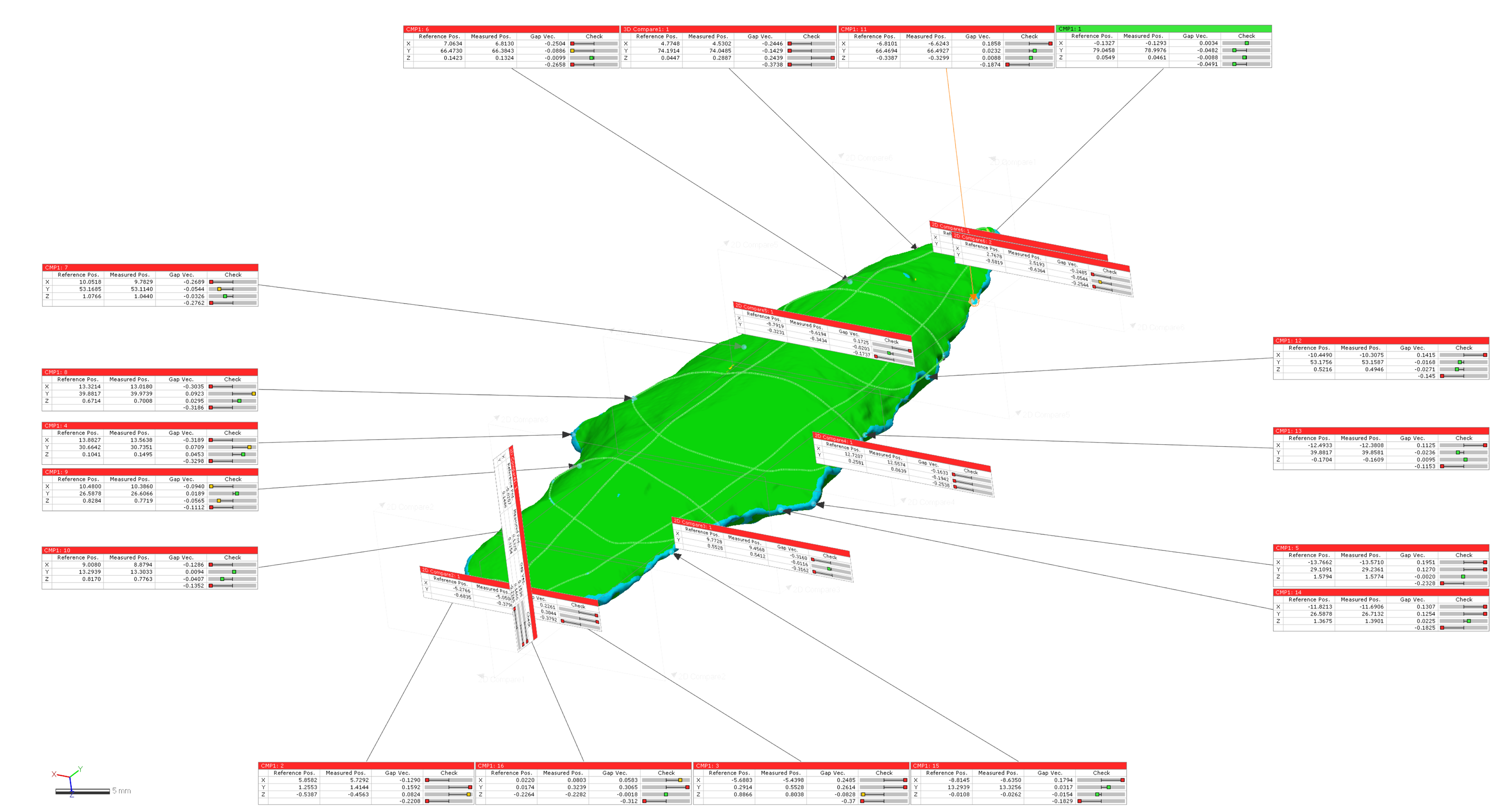


Preliminary results reported here include only the laser-scanned data; however, findings demonstrate that differences in scan data follow the edge around the periphery of the projectile. This is noteworthy, as the bulk of geometric morphometric and morphometric measures are collected along these high-curvature areas of the mesh topology. An additional issue entails the absence of data from selected areas of the ReGen9 datasets. It was not expected that holes would be present in these data, which needed to be filled in advance of batch processing the scans in the *Rvcg* package. Holes encountered following ReGen were addressed through a subsequent mesh regeneration, and enlisted the option to fill holes.

The geometric morphometric analysis will use the *auto3dgm* package to align each of the microCT and laser scans using principal alignments and 1500 pseudolandmarks, and the topology of all meshes in this study is considered homologous. A novel landmarking protocol will be used to place landmarks around the sinuous edge, providing for a more focused analysis of the mesh where the greatest differences were identified with Geomagic Control X. Whether or not the results are statistically significant, variation that occurs across scanning outputs warrants additional scrutiny and research.

The exploratory results from the mesh comparisons in Geomagic Control X demonstrate that substantive differences in mesh topology manifest when meshes are processed at different resolutions. This finding alone requires that we urge caution in 3D studies where meshes are digitally aggregated from different laboratories or data producers; particularly if data are repurposed from different scanning modalities in the same study (i.e., laser, structured light, CT, and microCT), where the intricacies associated with data collection and processing differ most.

Thinking critically about where and how scan data originate is important in metrological and morphological studies. It is recommended that in those studies where 3D data is aggregated from digital repositories, that investigators download the unprocessed (raw) data, and process it themselves, enlisting a processing protocol that remains consistent across the entirety of the sample. It is also posited that higher-resolution scan data will have greater utility and reuse potential over time, since all scan data can be downsampled, but no methods exist to increase the resolution of previously-scanned data.



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Data Availability Statement: The files and code associated with this project are available on GitHub (https://github.com/seldenlab/proc3dmesh), and are digitally-curated on the Open Science Framework (DOI: 10.17605/OSF.IO/H6YKX). Components of the curated project include the unprocessed 3D scan data (DOI: 10.17605/OSF.IO/QSKUZ), exported meshes (DOI: 10.17605/OSF.IO/HX2MT), and the code used for processing and analysis (DOI: 10.17605/OSF.IO/48BYA). This project is in active development, and it should be expected that code snippets and chunks will change until the manuscript is published.