

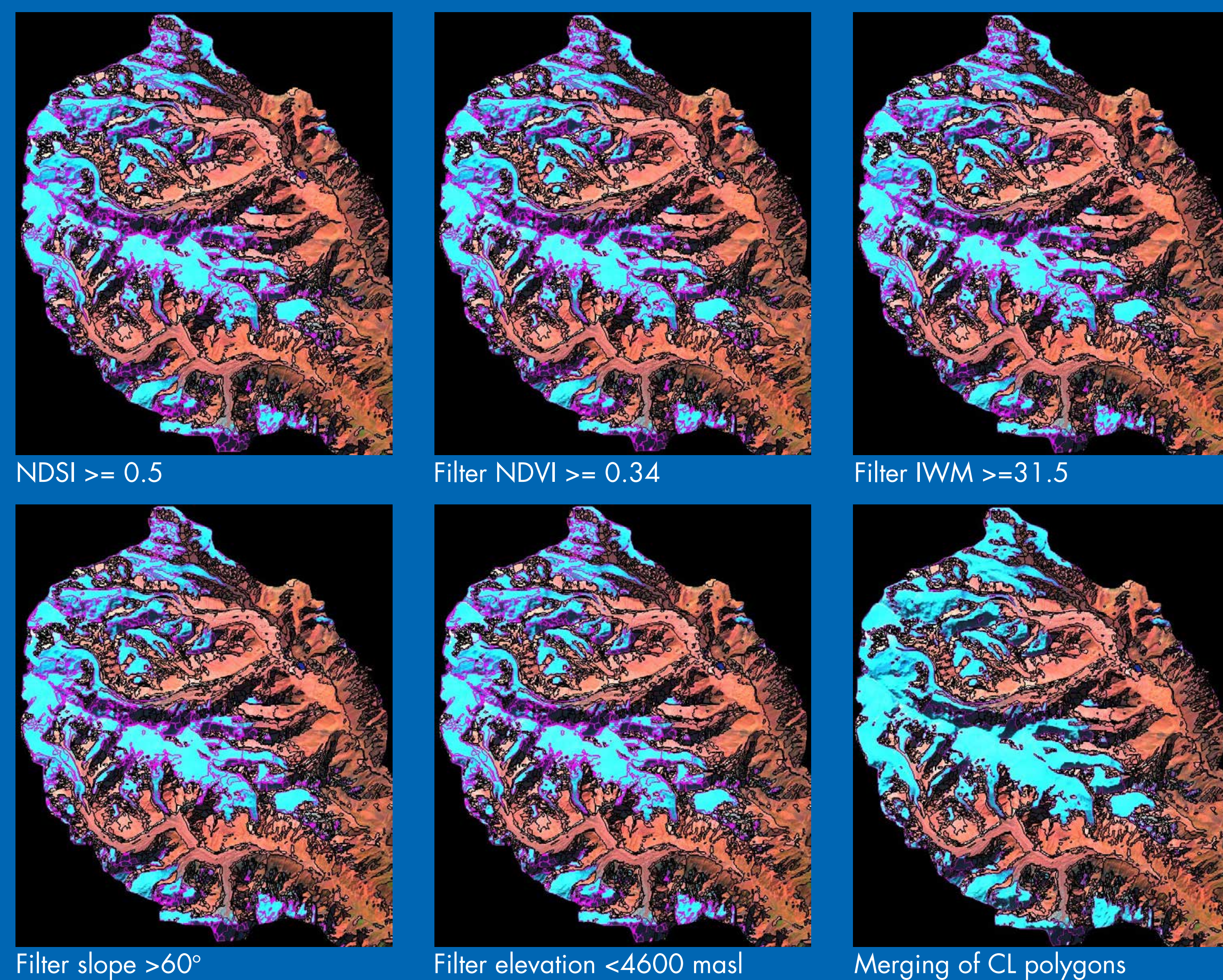
Methodology-Data Collection and Glacier Mapping

The increased availability of satellite data and advanced remote sensing tools and techniques has significantly improved mapping and monitoring of glaciers, especially in inaccessible regions. The present inventory used a combination of automated and manual interpretation of satellite images, complemented by limited field studies.

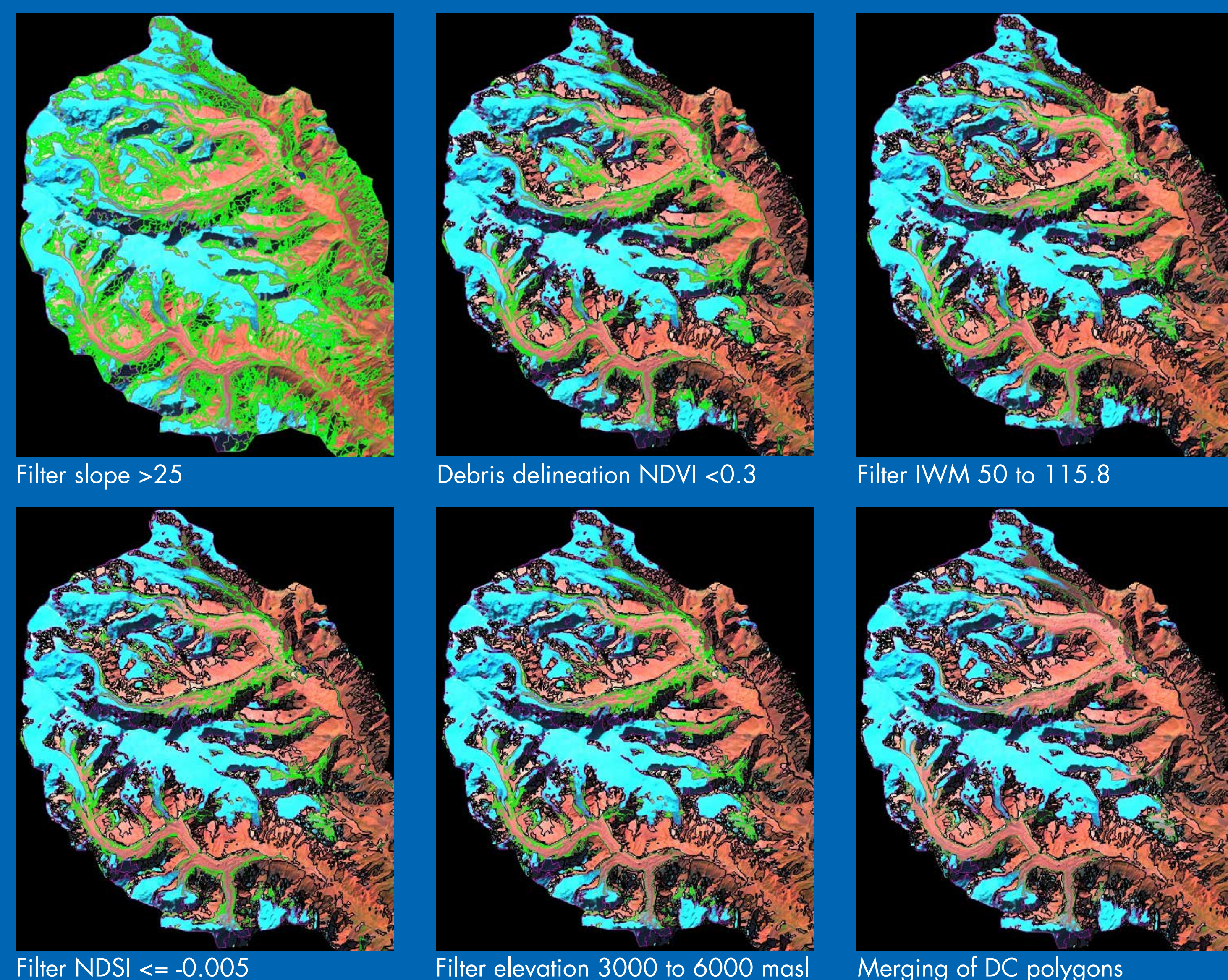
Mapping clean-ice (CI) and debris-covered (DC) glaciers

- The study used landsat image for glacier delineation and SRTM (Shuttle Radar Topography Mission) DEM of 90 m to derive glacier parameters like hypsometry, minimum/maximum/medium elevation, aspect, and slope.
- An object-based image analysis approach was used for glacier delineation. The image was segmented in Definiens Developer software using multi-resolution segmentation. Different algorithms were used to differentiate clean-ice (CI) glaciers and debris-covered (DC) glaciers based on their spectral characteristics.
- Clean-ice glaciers were identified primarily on the basis of the normalised difference snow and ice index (NDSI) with $NDSI = \frac{[Mean\ Band\ 2] - [Mean\ Band\ 5]}{[Mean\ Band\ 2] + [Mean\ Band\ 5]}$.
- Debris-covered glaciers were captured from the remaining unclassified image objects using slope threshold value of less than 25° and elevation between 6,000 to 3,000 masl depending on the locality.

Steps used in CI delineation

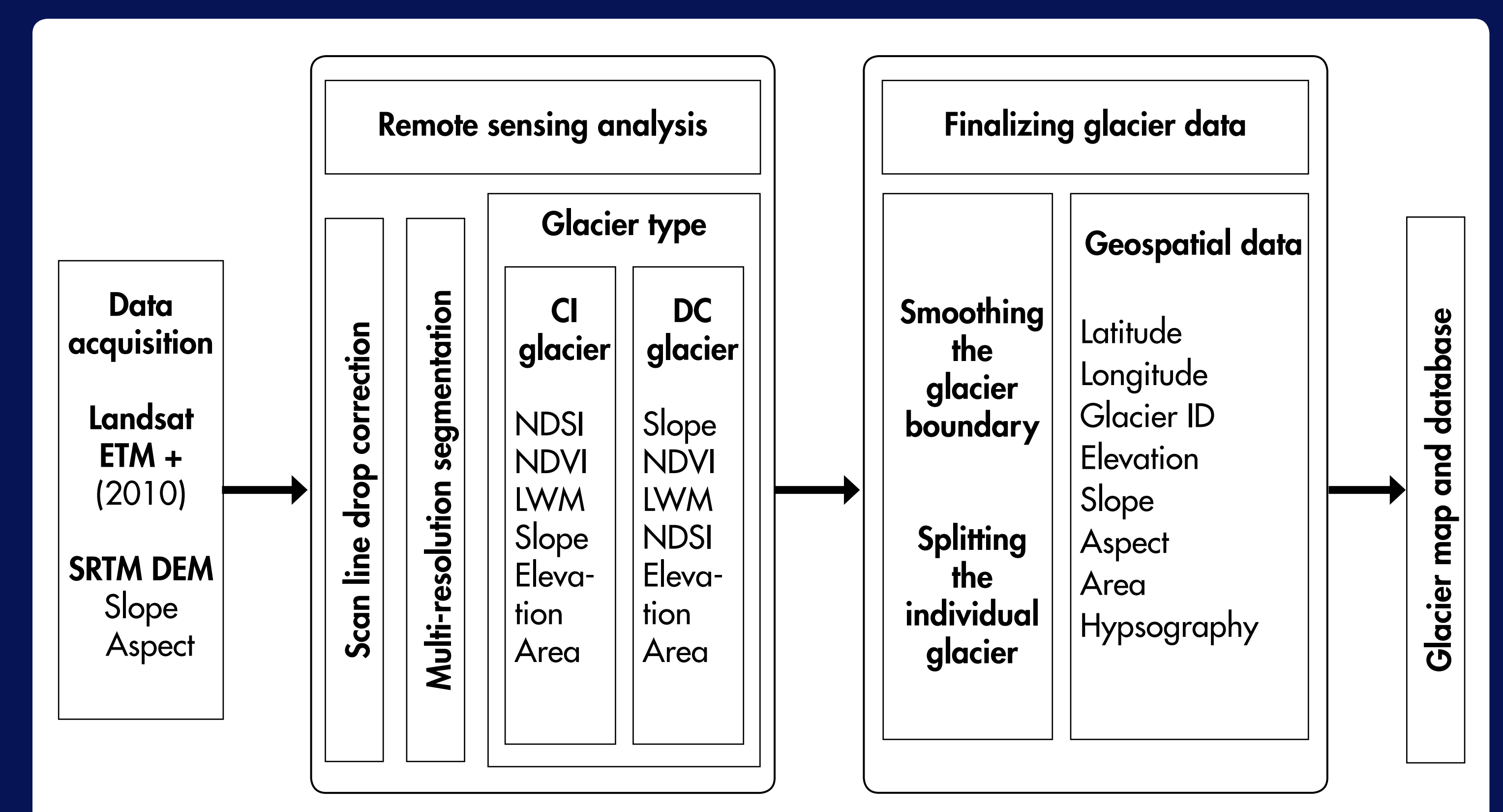


Steps used in DC delineation



- Other features such as vegetation, bedrock and shadows were also captured. These were then removed using filters.
- The outline of glaciers were finalised with some manual editing at a scale of 1:20,000 by draping over high resolution image from Google Earth.
- The glacier polygons were exported into shp file format for further processing and the glacier outlines were refined using the G-S-G (generalise – smooth – regeneralise) method.
- The CI and DC glacier polygons derived from the above processes were then merged into a single polygon layer.
- The post-classification data management and parameterisation were carried out in an ArcGIS platform.
- The glacier outlines for the other years (2000, 1990, and 1980) were then generated by manual modification using overlays of the satellite images from the respective years.

Flow diagram of the methodology used for mapping clean-ice and debris-covered glaciers using satellite images



Successive steps used to delineate glacier boundaries

