DrukRef23

National Reference Frame of Bhutan

NTv2 Transformation

DrukRef03 -> DrukRef23

Summary Report

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Executive Summary

Bhutan has introduced DrukRef23, a new national geodetic reference frame aligned to ITRF2020 at epoch 2023.5, replacing the earlier DrukRef03 system established two decades ago. Because Bhutan lies within an actively deforming region of the India–Eurasia collision zone, the differences between DrukRef03 and DrukRef23 are spatially variable, reaching approximately one metre across the country. These variations cannot be represented by a single Helmert transformation, requiring instead a grid-based approach.

To support national cadastral and mapping operations, a 10-arcsecond NTv2 transformation grid has been developed. It provides complete coverage of Bhutan and models the horizontal distortions accumulated since the adoption of DrukRef03. The grid delivers sub-decimetre accuracy when transforming legacy coordinates to DrukRef23 and preserves parcel area integrity within Bhutan's legal and operational tolerances.

The NTv2 file is supplied in standard formats and is fully compatible with mainstream GIS and surveying software (e.g., PROJ, QGIS, ArcGIS). It offers a robust, documented mechanism for migrating all national geospatial datasets to DrukRef23, ensuring continuity in land administration, surveying, and cartographic production. Future refinements to the grid can be incorporated as new geodetic control becomes available, without redefining the national datum.

1 Methodology

The development of the DrukRef03→DrukRef23 transformation required a method capable of representing spatially varying horizontal differences between the two reference frames. DrukRef03 was realised two decades ago from sparse, campaign-style GNSS observations, whereas DrukRef23 is aligned to ITRF2020 at epoch 2023.5 and realised through a modern CORS network. Over the intervening period, ongoing tectonic motion has produced position changes of the order of one metre across Bhutan. These temporal shifts, combined with heterogeneous legacy control, result in differences that cannot be represented satisfactorily by a single Helmert transformation. A grid-based NTv2 model was therefore adopted to capture the required spatial detail.

A consistent set of coordinates in DrukRef23 was first established for the CORS network using daily PPP solutions aligned to ITRF2020. To obtain paired coordinates suitable for modelling, 6 295 legacy cadastral ground control points referenced to DrukRef03 were re-observed using a combination of RTK and static GNSS methods tied to the CORS network. These observations yielded DrukRef23 coordinates for each point, allowing $\Delta\phi$ and $\Delta\lambda$ to be computed. Rigorous quality control—covering metadata consistency, observation type, formal uncertainty, repeatability and monument integrity—was applied to screen the dataset. After filtering, 5 753 points were retained as the transformation control set.

Using these paired coordinates, a series of native NTv2 grids was created at several resolutions: 10", 20", 30", 60", 90", 120", 240", 360", 540" and 720". These grids were estimated independently, with spatial detail governed by the local density and quality of the control points. Small or isolated cells were removed to ensure stability. All native grids were then resampled to a common 10" structure, and at each location the value from the finest available resolution was selected. This process ensures that detailed behaviour is preserved where supported by data, while coarser grids provide continuity in areas with sparser control.

2 Results

The NTv2 transformation surface was estimated from the filtered set of 5 753 control points, which provide nationwide coverage with variable local density. These points capture both the broad horizontal displacement accumulated between the epochs of DrukRef03 and DrukRef23 and the shorter-wavelength inconsistencies inherent in the legacy DrukRef03 control. The modelling produced a series of native grids at multiple resolutions, and these were combined into the final 10" transformation grid by selecting, at each location, the value from the finest resolution supported by the data.

The spatial pattern of the final transformation grid is shown in Figure 1. The field exhibits a clear south-to-north gradient, reflecting the cumulative effect of tectonic motion over the last two decades, with larger shifts in the southern part of Bhutan and progressively smaller values towards the north. Superimposed on this long-wavelength signal are local variations originating from heterogeneous survey campaigns and differing reference-

station configurations used during the original DrukRef03 observations. These finer-scale features are preserved where control density and quality permit; in areas with sparse or inconsistent observations, the final grid follows coarser-resolution surfaces to avoid introducing unsupported detail.

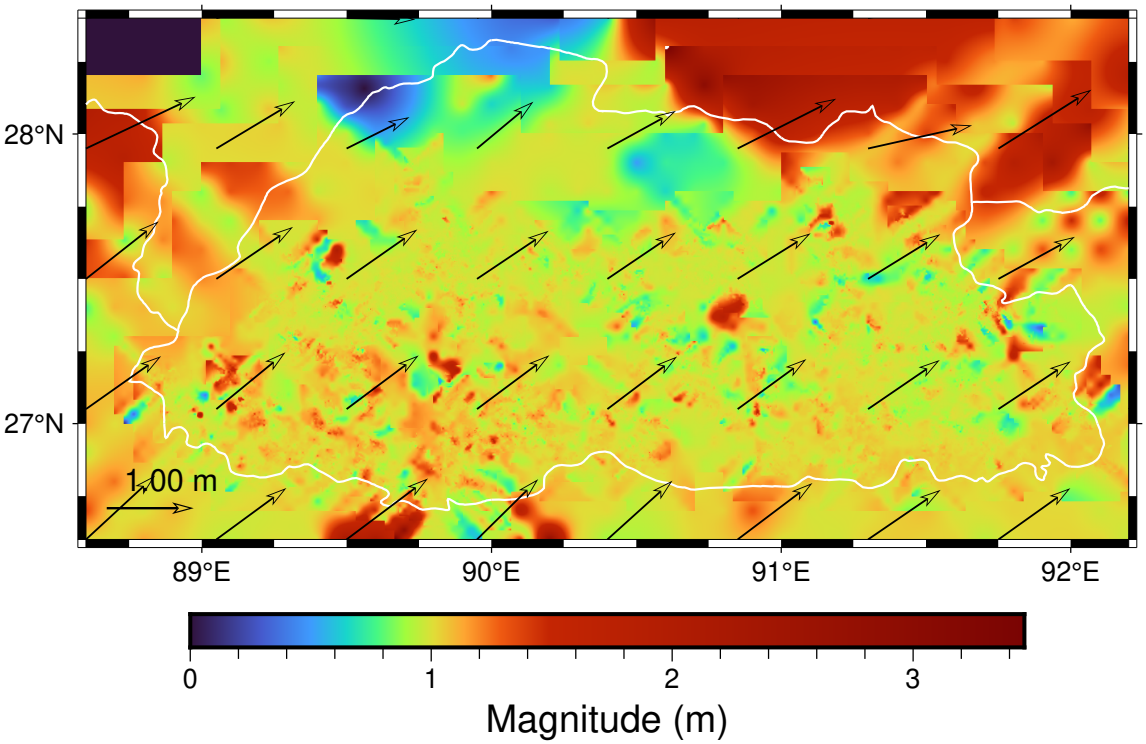

Figure 1 – Final 10" NTv2 horizontal-shift field (DrukRef03 → DrukRef23) over Bhutan (please note the boundary line is not official.

Comparisons between the native grids and the compiled 10" grid confirm that the resolution-selection strategy performs as intended: fine-resolution values are retained wherever available, and coarser grids provide continuity where necessary. Differences between native and final grids remain small in regions where several resolutions overlap; larger discrepancies occur mainly near the boundaries of coarse-resolution areas, typically outside Bhutan or in regions without cadastral impact.

The resulting 10" NTv2 grid provides a coherent and continuous national model of the horizontal shifts between DrukRef03 and DrukRef23 and incorporates all spatial variability supported by the underlying control dataset.

3 Technical Information

3.1 Specifications

- **Grid format:** NTv2 (GSA and GSB)
- **Components:** Δϕ (latitude), Δλ (longitude)
- **Resolution:** 10" × 10"
- **Coordinate order:** latitude, longitude
- **Geographic limits:** latitude 26.5º N-28.3ºN and longitude 88.6ºE-92.2ºE
- **Coverage:** full Bhutan extent, including a surrounding buffer
- **Interpolation method:** bilinear (NTv2 standard)

3.2 Availability

The transformation resources for DrukRef03 → DrukRef23 are available at:

- ***https://miranet.nlcs.gov.bt/public/ntv2/***

Direct access:

- ***ASCII grid (GSA):*** *https://miranet.nlcs.gov.bt/public/ntv2/d03tod23.gsa*
- ***Binary grid (GSB):*** *https://miranet.nlcs.gov.bt/public/ntv2/d03tod23.gsb*
- ***Report (PDF):*** *https://miranet.nlcs.gov.bt/public/ntv2/ntv2_report.pdf*

3.3 Usage

PROJ (command line)

- *cs2cs +proj=longlat +nadgrids=/path/to/d03tod23.gsb +to +proj=longlat*

QGIS

- *QGIS uses GDAL internally, so the transformation is performed by opening the OSGeo4W Shell (Run as Administrator), inside the QGIS installation folder, ensuring GDAL has permission to read the NTv2 grid (d03tod23.gsb).*
- *Run the transformation command (ogr2ogr, gdalwarp) using the NTv2 grid (d03tod23.gsb) and the LCC target CRS parameters (see file https://miranet.nlcs.gov.bt/public/ntv2/QGIS_Transformation_Commands.pdf)*

ArcMap / ArcGIS Pro

- *Install the NTv2 grid (d03tod23.gsb) in the ArcGIS NTv2 directory to make it available for geographic transformations:*
  - *C:\Program Files\ArcGIS\Desktop10.x\pedata\ntv2\ (For ArcMap)*
  - *C:\Program Files\ArcGIS\Pro\Resources\pedata\ntv2\ (For ArcGIS Pro).*
- *Register the transformation using Create Custom Geographic Transformation in ArcMap/ArcGIS Pro.*
- *Apply the transformation when reprojecting vector or raster datasets using the Project (vector) or Project Raster (raster) tools.*