Using NTv2 Files for Datum Transformations in Deforming Regions: The Cases of Bhutan and Chile

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Introduction

- Geocentric Datums based on modern space-geodetic techniques (mainly GNSS) have been adopted worldwide as National Reference Frames.

- Such Datums are nowadays mainly permanently materialized through networks of CORS (Continuously Operating Reference Stations) GNSS stations instead of passive reference control points.

- GNSS CORS based Datums has many advantages compared with Classical Datums based on passive control points:

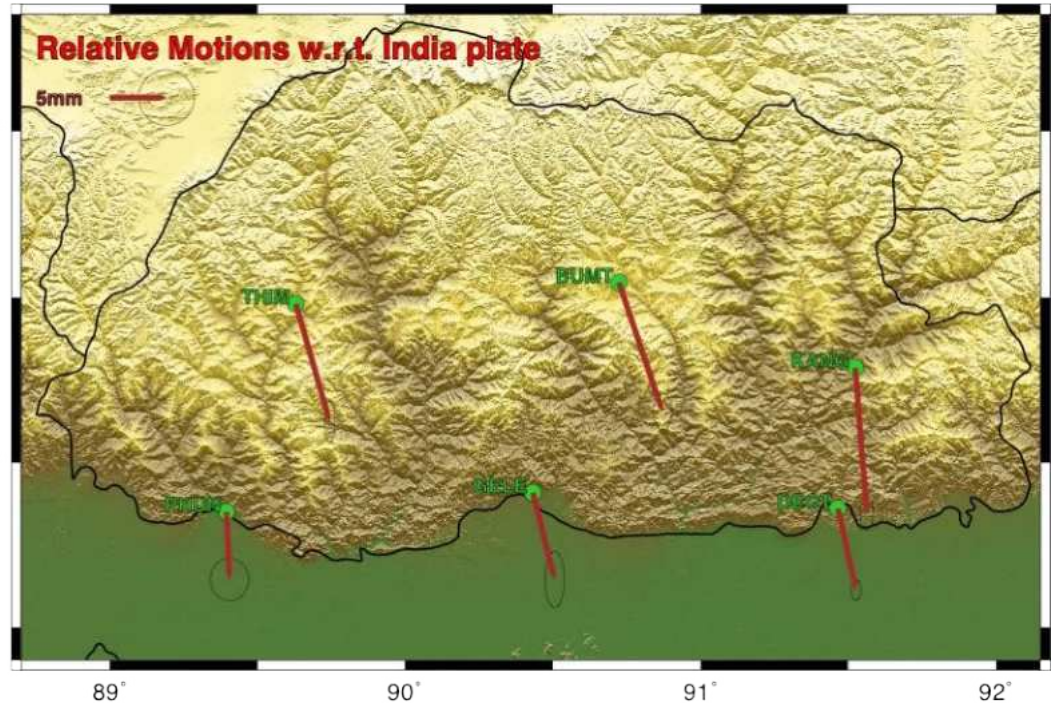
Introduction

- *GNSS CORS based Datums has many advantages compared with Classical Datums based on passive control points*:
  - Permanent materialization of the reference network since the CORS stations are continuously acquiring the data.
  - Permanent monitoring of the stability of the network – any change in the positions is noticed – the same is not true for passive control points.
  - The internal accuracy of the fiducial network is few millimeter level.
  - No need for passive control points when carrying out surveying in the vicinity of the CORS station (up to 25-30Km).
  - Direct connection to the international reference frames, namely ITRFxxx, which facilitates the integration of international projects (e.g., definition of borders).
  - Use of the most modern geodetic techniques which will contribute to modernize and transfer of knowledge to the Surveyors community.
  - Possibility to monetize the access to RTK corrections generating income to governmental authorities.

Introduction

- Not only Classical Datums need to be updated to Geocentric Datums!
- In Deforming Regions, modern Geocentric Datums also need to be regularly updated.
- Bhutan example:

  Since 2003, when DrukRef03 (the 1st geocentric datum of Bhutan) was defined, the total shortening of the baselines between stations in the southern part of the country and stations in the central part is already about 9-10cm.



Introduction

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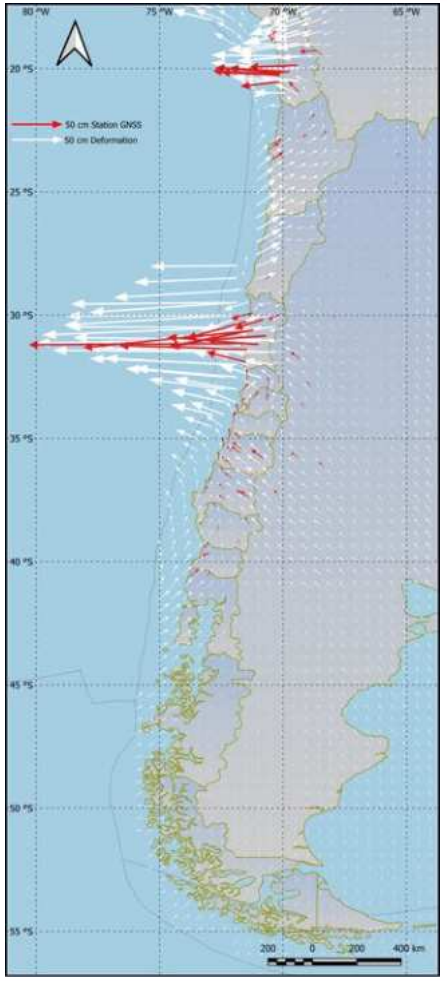
- Chile example:



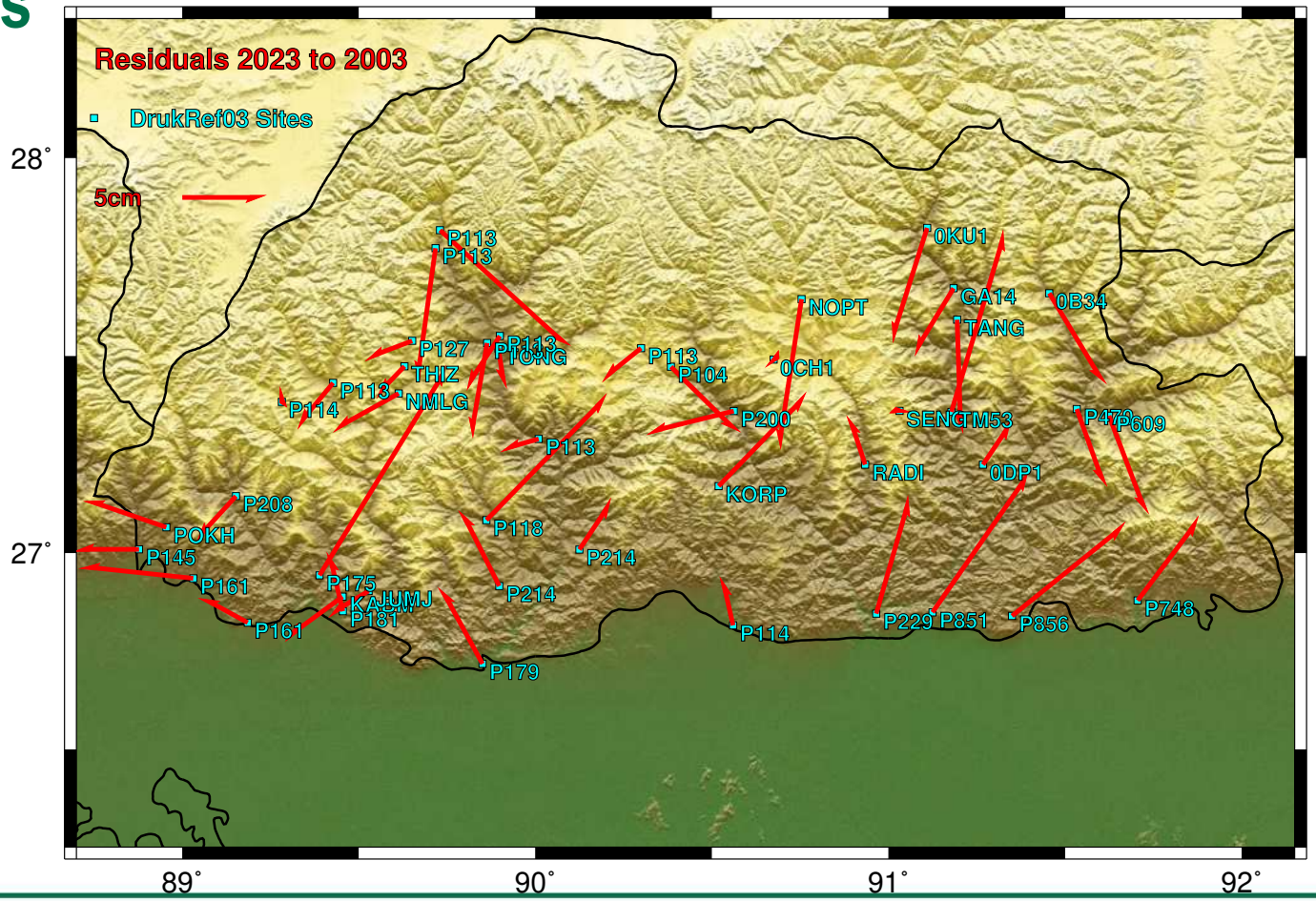
Chile is regularly affected by large earthquakes which co-seismic displacements can reach several meters

Introduction

- The adoption of a new geocentric datum requires the estimation of transformation parameters between the old datum and the new datum.
  - This is essential to convert all existing geo-referenced information (cadastral, maps, engineering projects) acquired in the old datum into the new datum.
  - Cadastral information, in particular, has strict accuracy requirements (few centimeters) since areas should not change significantly when new coordinates are assigned to the plot's boundaries.

7-Parameter (Helmert) Transformations

- Helmert is a Conformal Transformation: it does not change shapes.
- A unique national-wide 7-parameter (Helmert) transformation is unable to minimize errors due to:
  - past measurements using classical techniques (significantly less accurate than the modern space-geodetic techniques)
  - active deformations due to plate tectonics.



7-Parameter (Helmert) Transformations

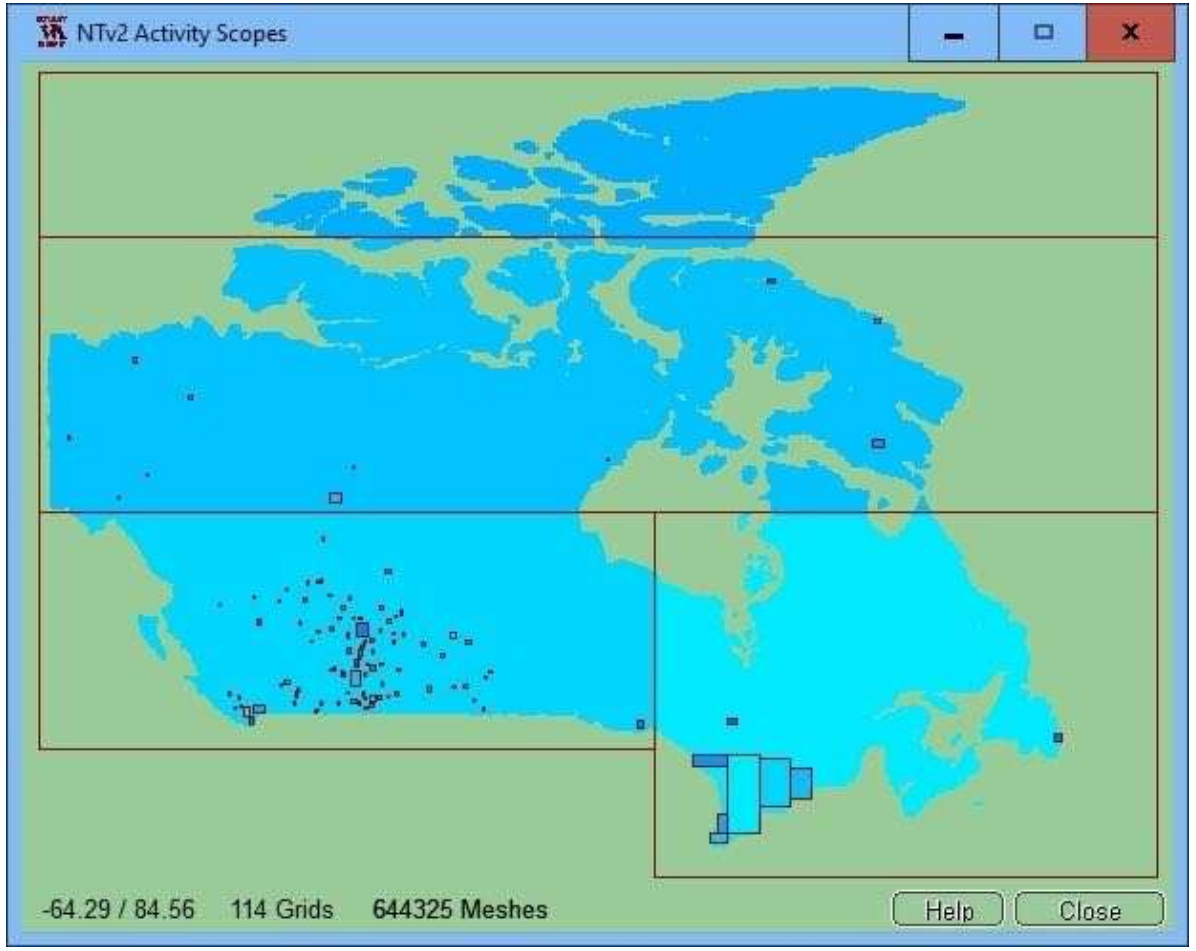
- Chile:
  - The geodetic measurements of Classical Datums (PSAD56 and SAD69) were made in the 50s to 70s.
  - The transformation parameters between the classic and modern (SIRGAS) are made available only for cartography, scale 1:25000. The accuracy is ± 17 m (according to EPSG).

Ntv2 Transformations

- NTv2 (National Transformation Version 2) is a grid-based format widely used for datum transformations. It offers several advantages over 7-Parameter Transformations:
  - Higher Accuracy: NTv2 transformations account for variations due to internal deformations and/or observational errors.
  - Local Adaptation: can be customized for specific regions, capturing local geodetic anomalies and irregularities.
  - Efficiency: once the grid is established, NTv2 transformations can be applied quickly and efficiently to large datasets.
  - Versatility: NTv2 can be used for both horizontal and vertical transformations.
  - Broad Software Support: Many geospatial software packages support NTv2 transformations.
  - Maintenance: They can be regularly updated to reflect the latest geodetic measurements and models.

Ntv2 Transformations

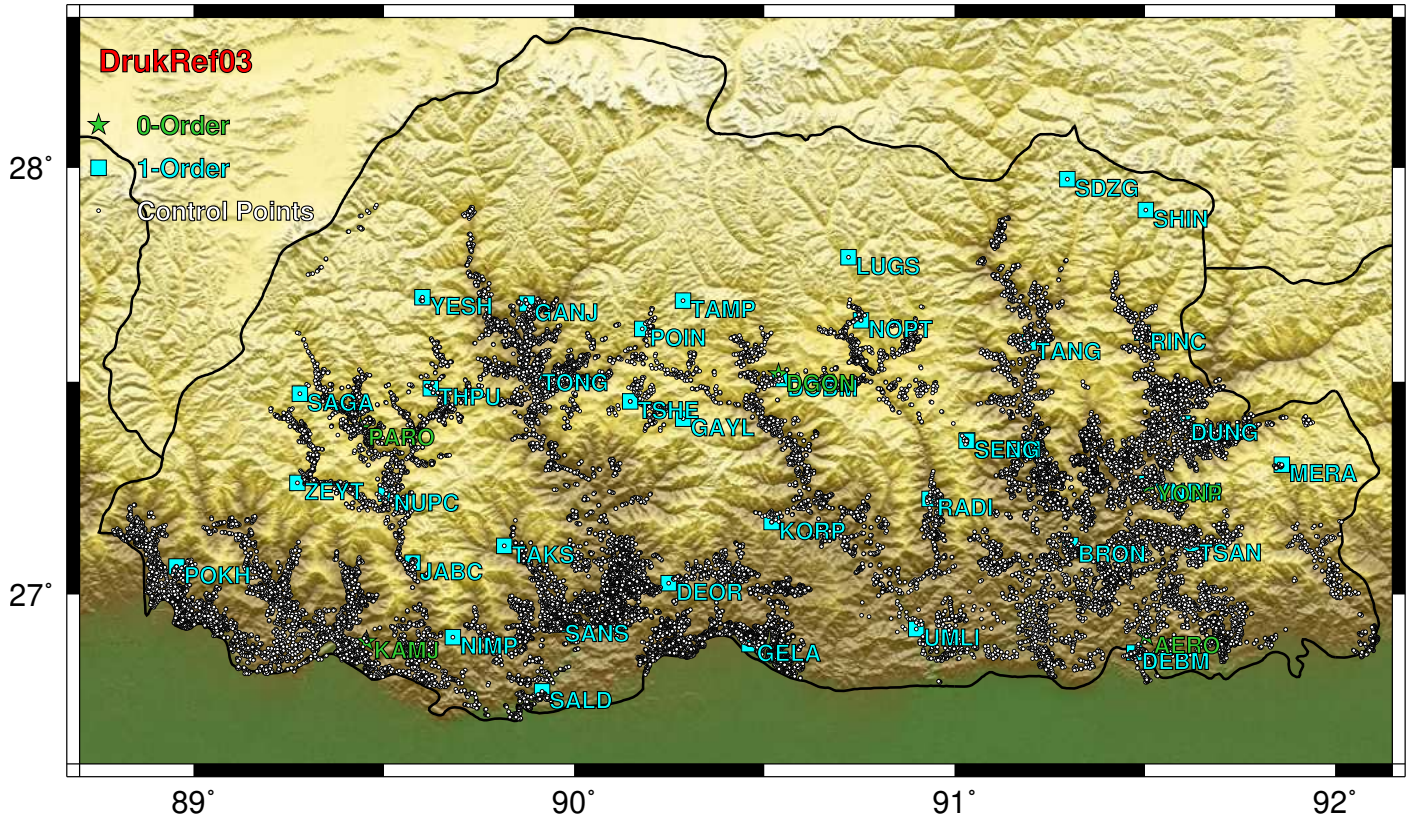
- NTv2 (National Transformation Version 2) was initially developed by the Geodetic Division of Natural Resources of Canada being nowadays officially in use in many countries worldwide.
  - It is formed by 114 grids of different sizes containing 644325 meshes.
  - The magnitude and direction of the correction is given at each corner of the mesh so the correction for each point of interest can be computed by interpolation



Bhutan Example (Transformation from DrukRef03 into the new DrukRef23):

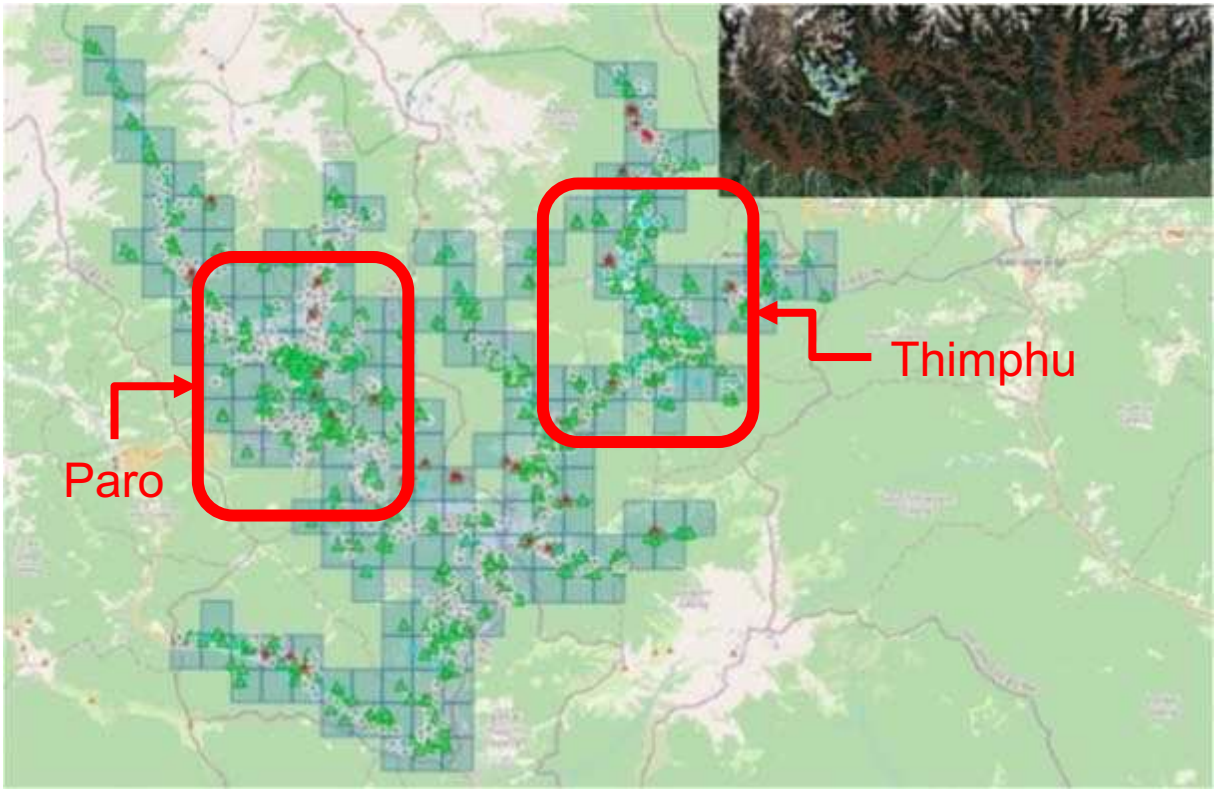
- There are approximately 27200 passive control points distributed in the country mainly established for acquiring cadastral information w.r.t. DrukRef03.

- They are heterogenous spatially distributed and the quality also greatly varies since they were computed using different methodologies (RTK, Classical Observations) at many different epochs.



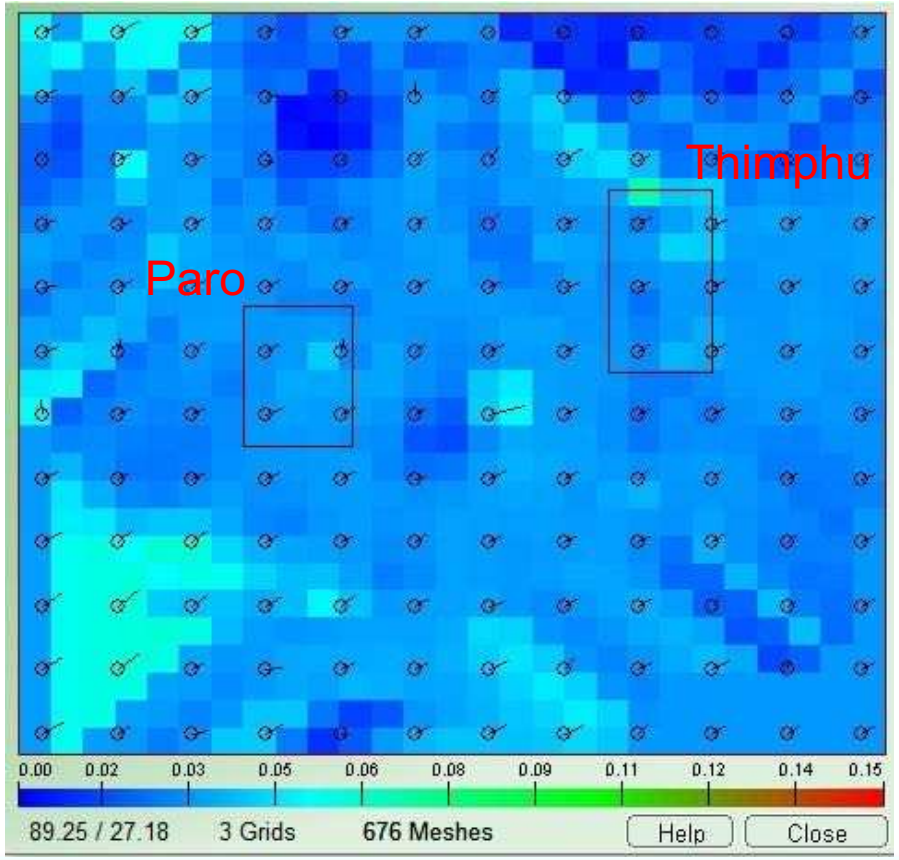
Bhutan Example (Transformation from DrukRef03 into the new DrukRef23):

- Phase 1 focused on Thimphu (capital) and neighboring Paro Dshonks (districts) to:
  - fine-tune field work procedures
  - evaluate the quality of the derived NTv2 files
  - 580 control points were observed in RTK mode
  - 223 points are destroyed or could not be reobserved.



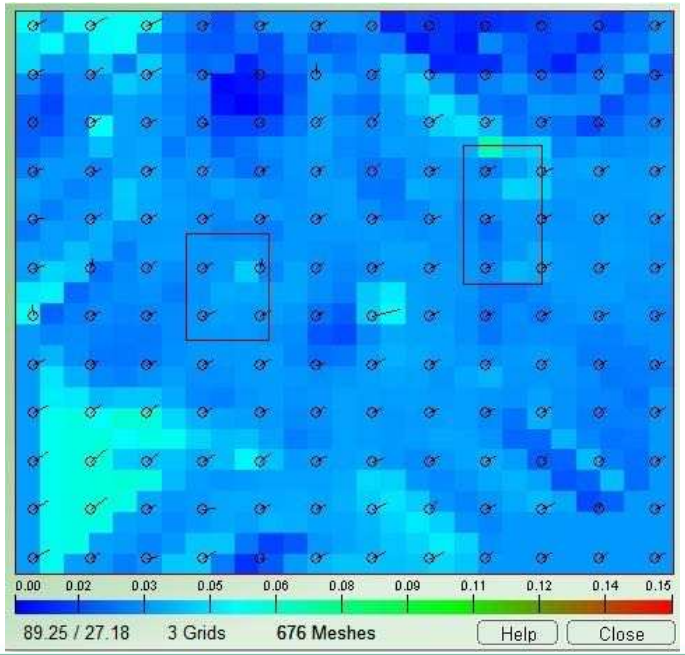
Bhutan Example (Transformation from DrukRef03 into the new DrukRef23):

- Three Grids were computed:
  - One covering the entire observed area
  - Two covering the urban areas of Thimphu and Paro
  - The main grid will be recomputed when the remaining districts will be observed during Phase 2 of the project (planned to start in July).



Bhutan Example (Transformation from DrukRef03 into the new DrukRef23):

- The width (and consequently the number) of each mesh is an important factor to achieve the best accuracy.

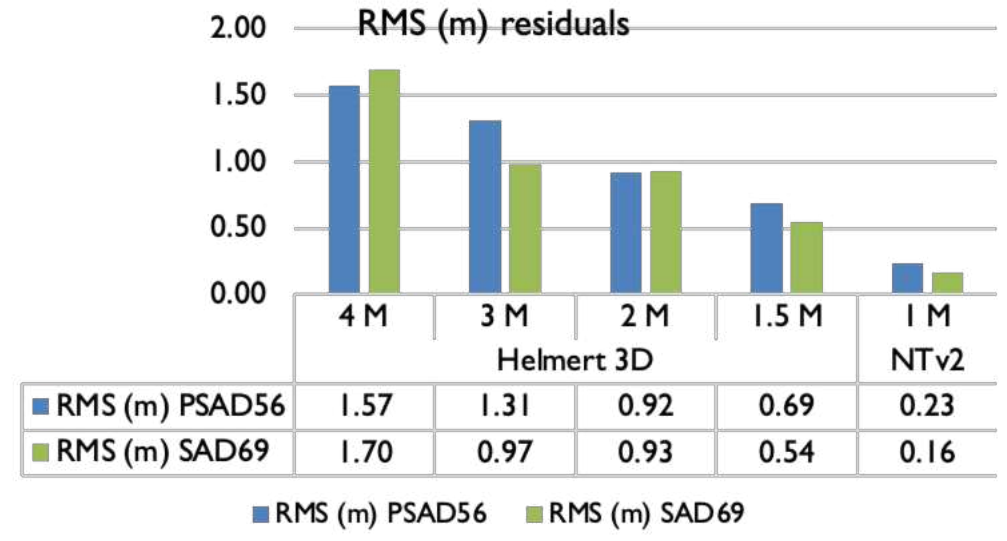


Entire Area			
X (km)	Y (km)	Meshes	Mean Error (mm)
0.567	0.482	12753	136.3
1.133	0.965	3245	90.1
1.700	1.447	1369	82.3
2.267	**1.930**	**729**	**72.4**
2.494	2.123	625	83.0
3.400	2.895	361	83.0
Thimphu Grid			
X (km)	Y (km)	Meshes	Mean Error (mm)
0.293	0.513	552	163.1
0.439	0.770	256	153.2
0.586	1.026	144	69.4
0.850	1.488	90	44.9
0.879	**1.539**	**81**	**34.2**
0.908	1.591	90	66.9
0.937	1.642	64	74.6
Paro Grid			
X (km)	Y (km)	Meshes	Mean Error (mm)
0.370	0.393	462	105.8
0.555	0.590	240	78.6
0.739	0.787	121	76.8
1.109	**1.180**	**72**	**66.1**
1.294	1.377	56	74.0
1.405	1.495	49	103.5
1.849	1.967	30	109.7

Chile Example (Transformation from Classical into Geocentric Datum):

- Two separate comparisons between Helmert and NTv2 transformations have been done between the Classical (PSAD56 and SAD69) and the new Geocentric Datum (SIRGAS).

- It is clear that NTv2 provides a much better adjustment in both cases.



	4 M	3 M	2 M	1.5 M	1 M
RMS (m) PSAD56	1.57	1.31	0.92	0.69	0.23
RMS (m) SAD69	1.70	0.97	0.93	0.54	0.16

Total Control Points			157		
Selected Control Points	108	89	57	38	143

Total Control Points			20		
Selected Control Points	15	12	11	6	15

Conclusions:

- NTv2 (National Transformation Version 2) transformations, being able to accommodate and minimize internal deformations and/or observational errors, provide better adjustments when it is necessary to transform existing geo-information from Classical to Geocentric Datums (or even new Geocentric Datums are computed).
- The two studied areas (Bhutan and Chile) clearly show the advantages of the NTv2 approach in high deforming areas.
- Bhutan also show the additional advantage of using grids with different mesh sizes (particularly useful when high accuracy is required like in urban areas).

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