Measurement of Height of Mt. Everest (Sagarmatha): Geodetic considerations

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Niraj Manandhar
Modernized geodetic datum aligned with ITRF2014 Coordinates transformed to 1 Jan 2016 using the a national deformation model
How the NDM works

Position vs. Time

Modernized datum coordinate

NDM

Patch

2005

Time

2016
Secular velocity field

- Velocity from four recent studies were aligned with the ITRF2014 velocities
Earthquake patches

April 2015 Mw7.8 Gorkha Earthquake

May 2015 Mw 7.3 Aftershock

Dislocation models  source:
Gorka Earthquake

Aftershock
Deformation models in survey adjustments
Example: Patch for an Earthquake

Measured Vector
Measured Position and Vector
Ground Displacement
Corrected Nepal2016 vector EPOCH 2016.0
Control

- The stations of the Nepal GNSS array were adopted as a 0 order network of CORS
- Coordinates determined processing 3.5 years of data using Bernese. Coordinates aligned to ITRF2014 at epoch 2016.0
First Order adjustment Preliminary results

- Data from 2009-2017
- 222 baselines 217 used 5 rejections
- Coordinates of 60 first order stations determined to 4th order standards
Combined vertical displacements from Gorka earthquake and May aftershock
Heights Based on Geopotential Number (C)

- **Normal Height (NGVD 29)**
  \[ H^* = C_N \bar{\gamma} \]
  \( \bar{\gamma} \) = Average normal gravity along plumb line

- **Dynamic Height (IGLD 55, 85)**
  \[ H^{\text{dyn}} = C / \gamma_{45} \]
  \( \gamma_{45} \) = Normal gravity at 45° latitude

- **Orthometric Height**
  \[ H = C / \bar{g} \]
  \( \bar{g} \) = Average gravity along the plumb line

\[ \Delta C_{b-a} = \sum_{a}^{b} \Delta h_i g_i \]
Geoid and Conversion Surfaces using GPS on BM data

- Gravimetric Geoid: systematic misfit to BM's but best fits "true" heights
- Conversion Surface: model of systematic misfit derived from BM's
<table>
<thead>
<tr>
<th>Coefficient of Refraction</th>
<th>Calculated Ortho. Ht (95% C.I.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>k derived from reference lines Adjusted k= 0.075</td>
<td>3703.31m*</td>
</tr>
<tr>
<td>Adjusted k from measured T&amp;P</td>
<td>3726.97m ± 1.38m</td>
</tr>
<tr>
<td></td>
<td>3725.14 ± 1.38m</td>
</tr>
</tbody>
</table>

Accepted height = 3724m

Tyler Hager
Summer Bursary Report
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Orthometric heights from adjustment

- Follow NGS59 Incorporate BM’s in survey
- **NSRS** cGNSS 75 km spacing
- **Primary** 40 km spacing 4 hr occupations
- **Secondary** 15 km 30 min sessions
- **Connect** each mark to 2 nearest stations
- **traceable** back to NSRS stations along two independent paths

NOAA Technical Memorandum NOS NGS 59
Guidelines for Establishing GPS-Derived Orthometric Heights
Control for Everest

- The Nepal GNSS array provide the high level (NSRS) control
- The Primary stations could be existing first order stations or new ones
  - Need to be sites to support the leveling lines
- Secondary stations would be benchmarks
Conclusions

• The new Nepal Datum is the best choice for the Sagarmatha Height Measurement Project SHMP
• The Nepal Vertical datum has been significantly distorted due to the 2015 Gorka Earthquake
• A systematic mismatch between leveling and gravimetric geoids is likely.
  • If uncorrected this will bias any attempt to determine orthometric heights from GNSS
• Good mets are the key to successful Trigonometric Levelling
• The Nepal cGNSS array is well configured to provide control for the SHMP with some augmentation
  • Lower order control surveys should follow NGS59