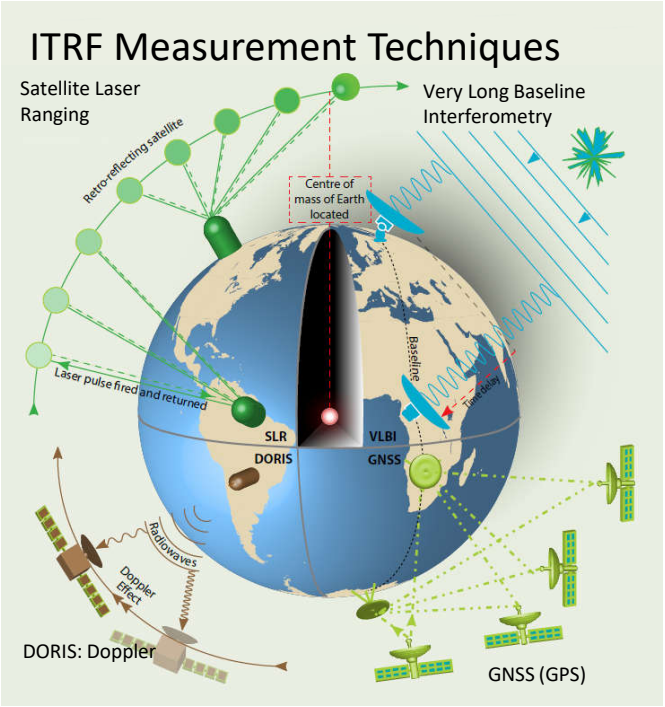
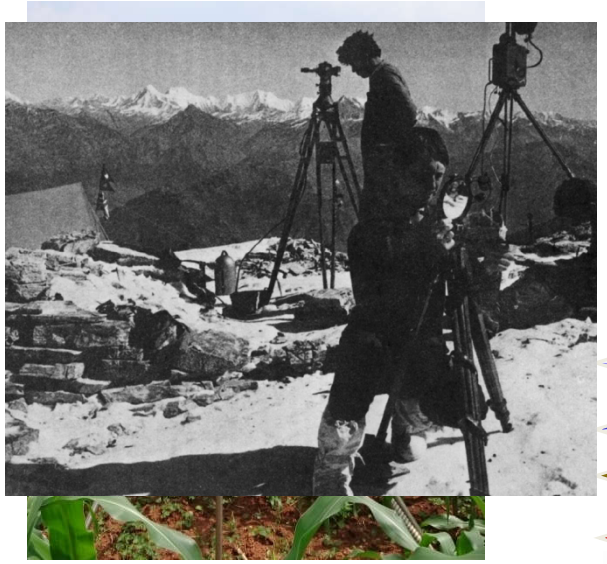
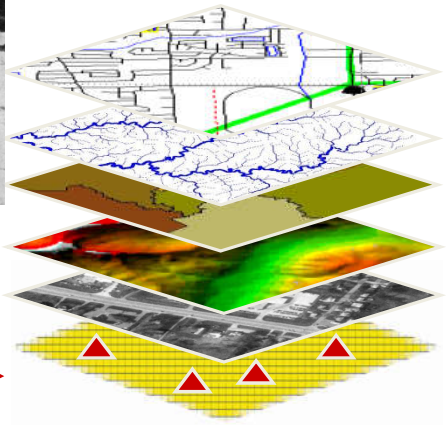
Measurement of Height of Mt. Everest (Sagarmatha): Geodetic considerations

Chris Pearson
Niraj Manandhar





ITRF2014 NDM



Required by GPS

No deformation model

Datums and epoch dates change frequently

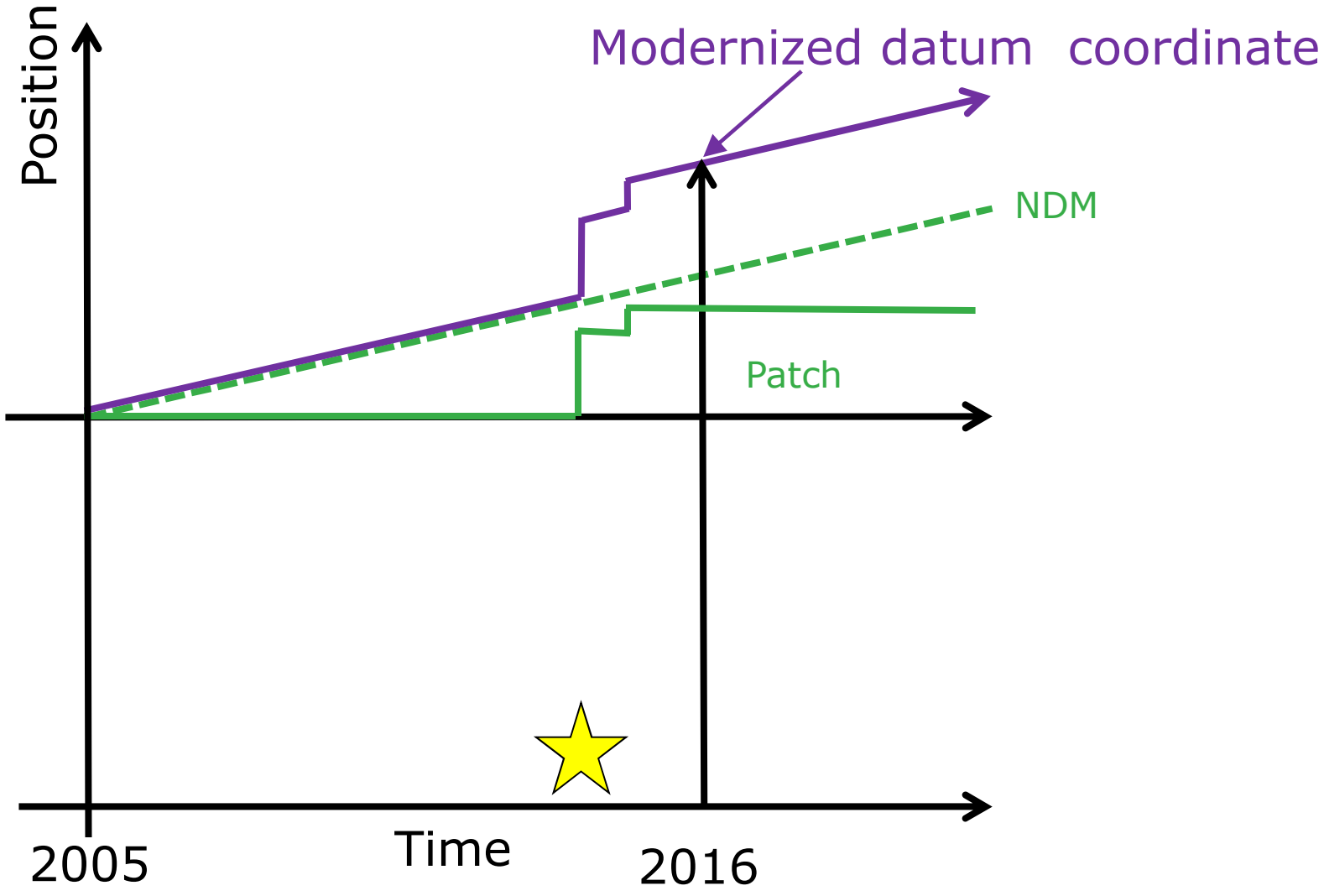
Modernized datum for Nepal

Stable coords

deformation model

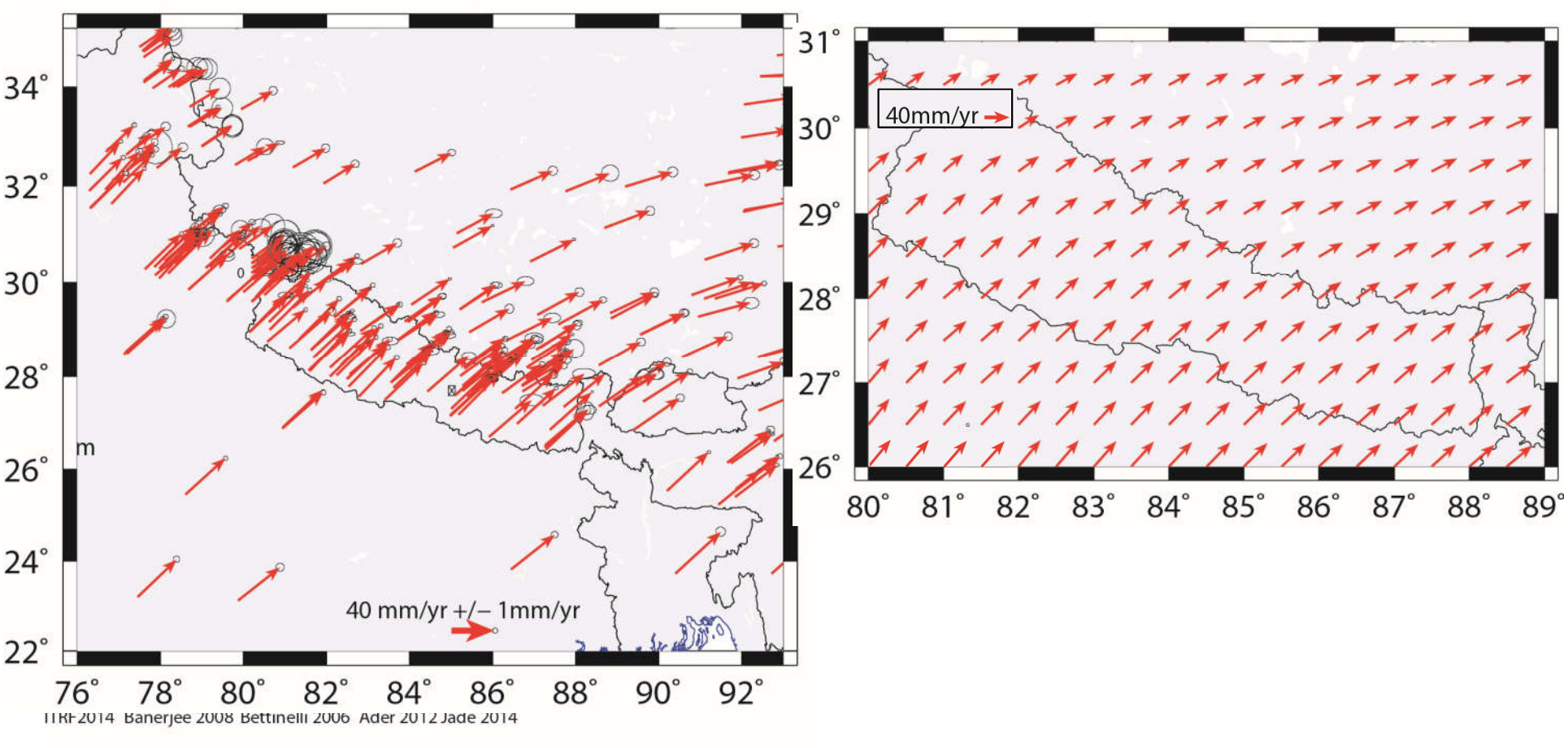
Modernized geodetic datum aligned with ITRF2014 Coordinates transformed to 1 Jan 2016 using the a national deformation model

How the NDM works



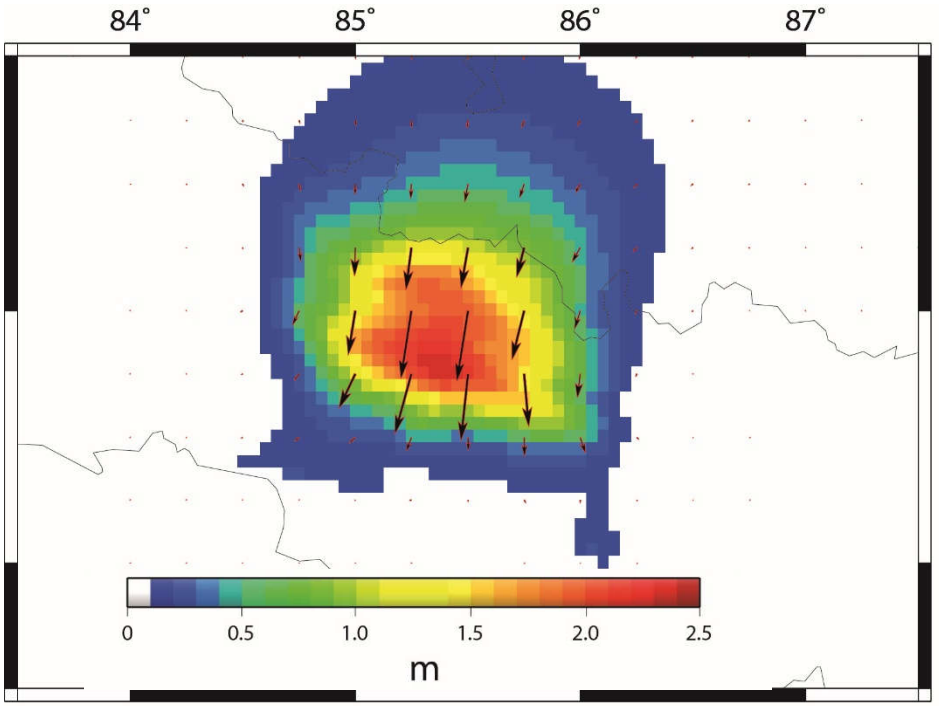
Secular velocity field

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

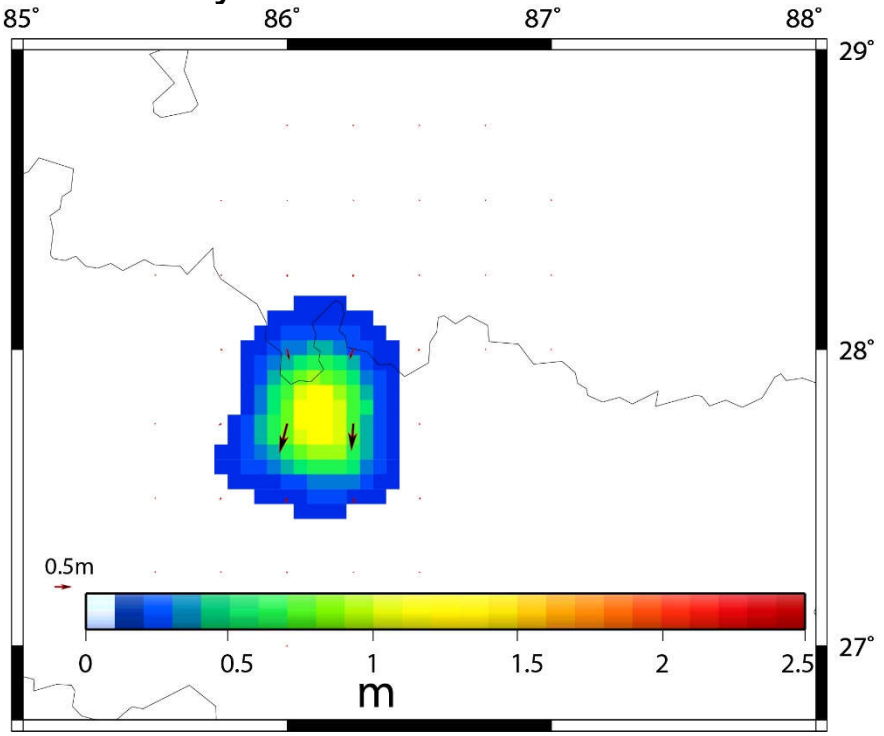


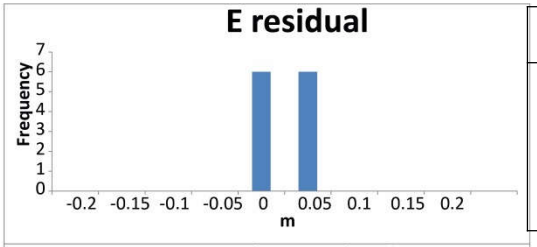
Earthquake patches

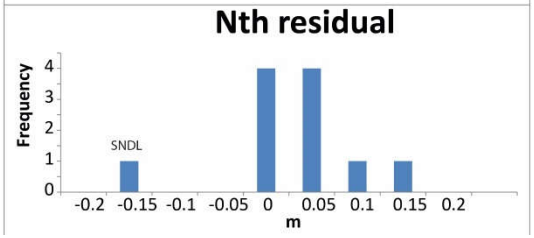
April 2015 Mw7.8 Gorkha Earthquake



May 2015 Mw 7.3 Aftershock







RMS	Wang
E m	0.07
N m	0.02
U m	0.03

Dislocation models source:

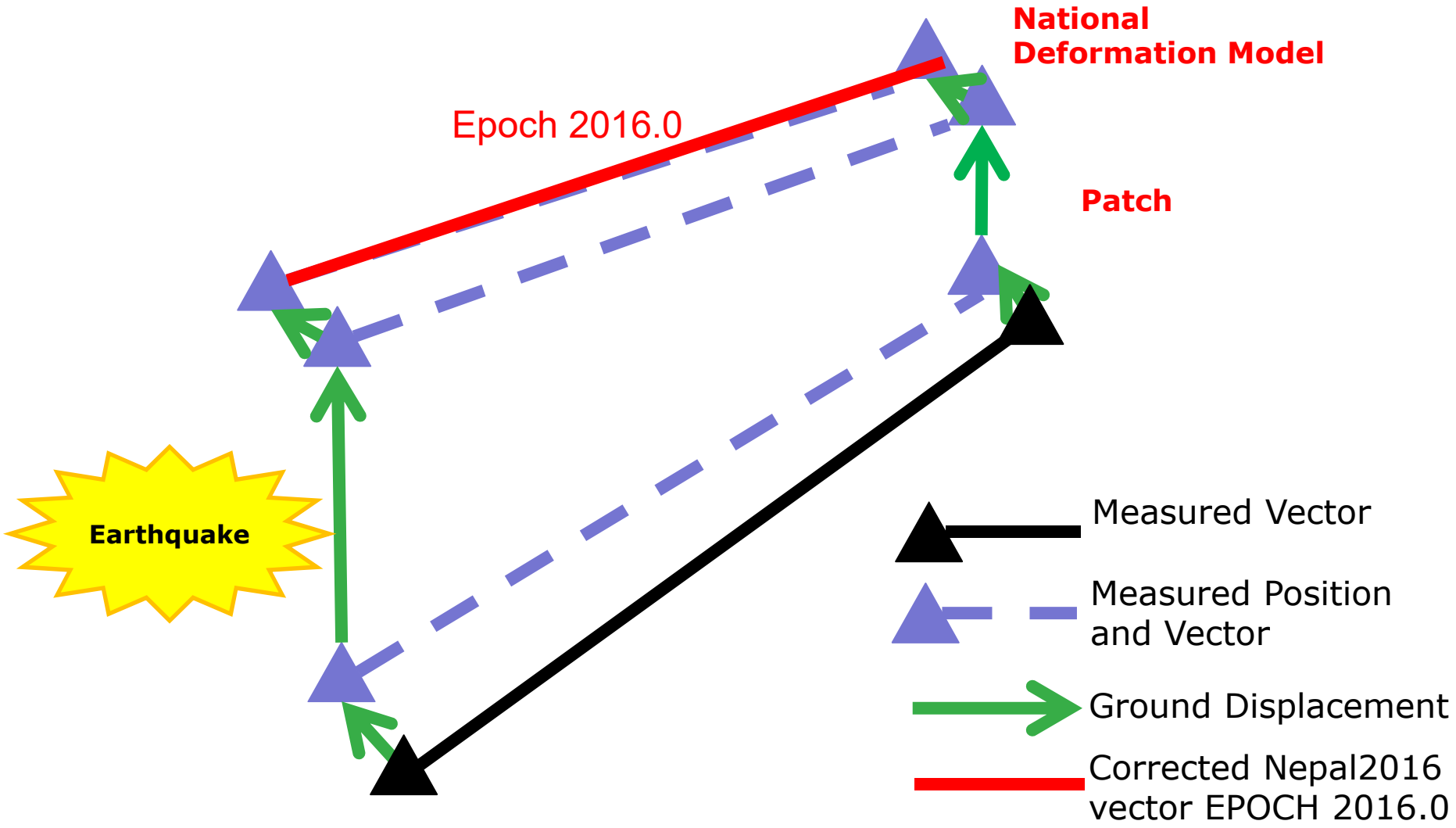
Gorka Earthquake

Wang, K., and Y. Fialko (2015), Slip model of the 2015 Mw 7.8 Gorkha (Nepal) earthquake from inver- sions of ALOS-2 and GPS data, Geophys. Res. Lett., 42, 7452–7458, doi: 10.1002/2015GL065201.

Aftershock

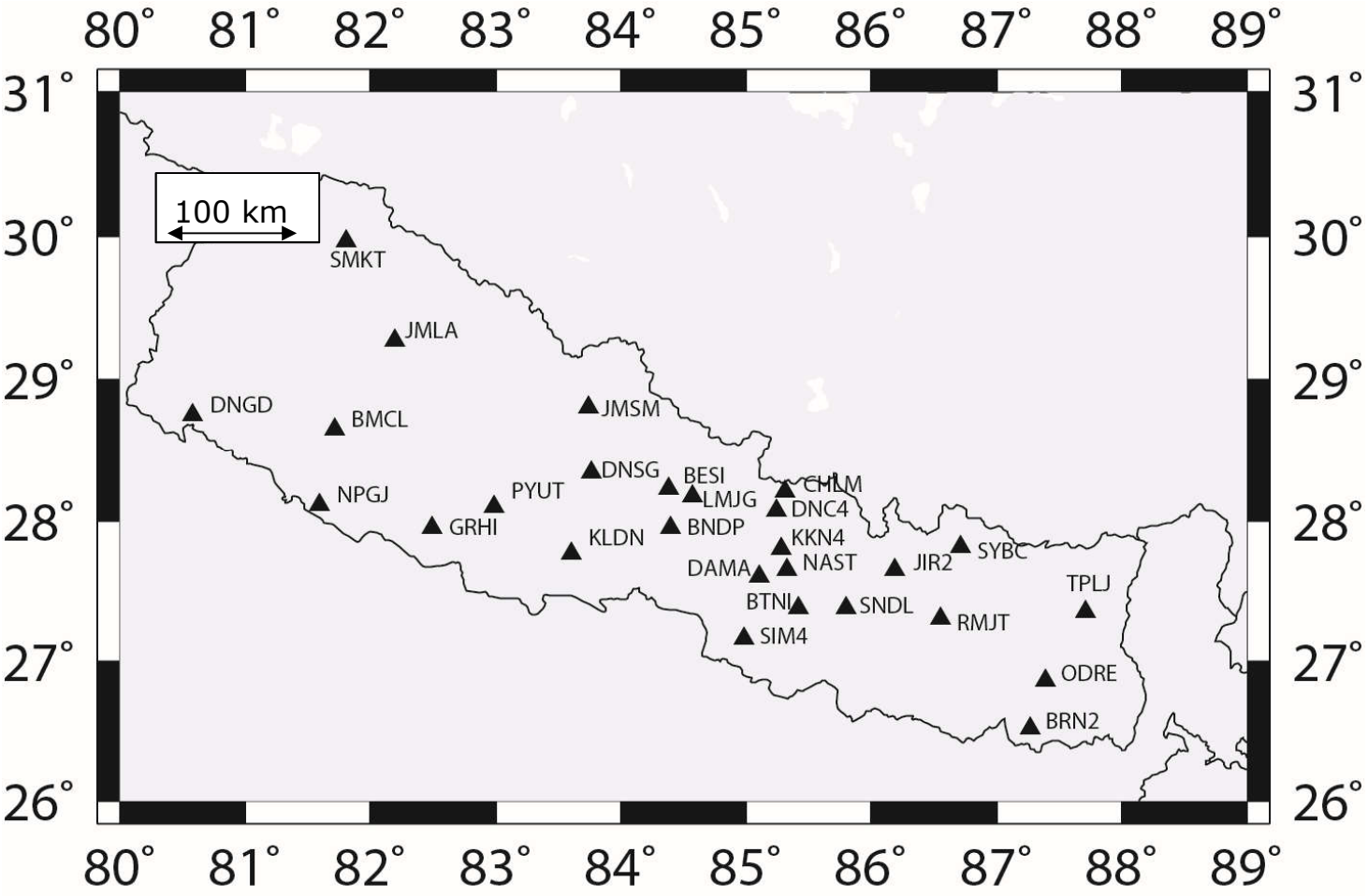
Wang K Pers. Com. 2017

Deformation models in survey adjustments
Example: Patch for an Earthquake



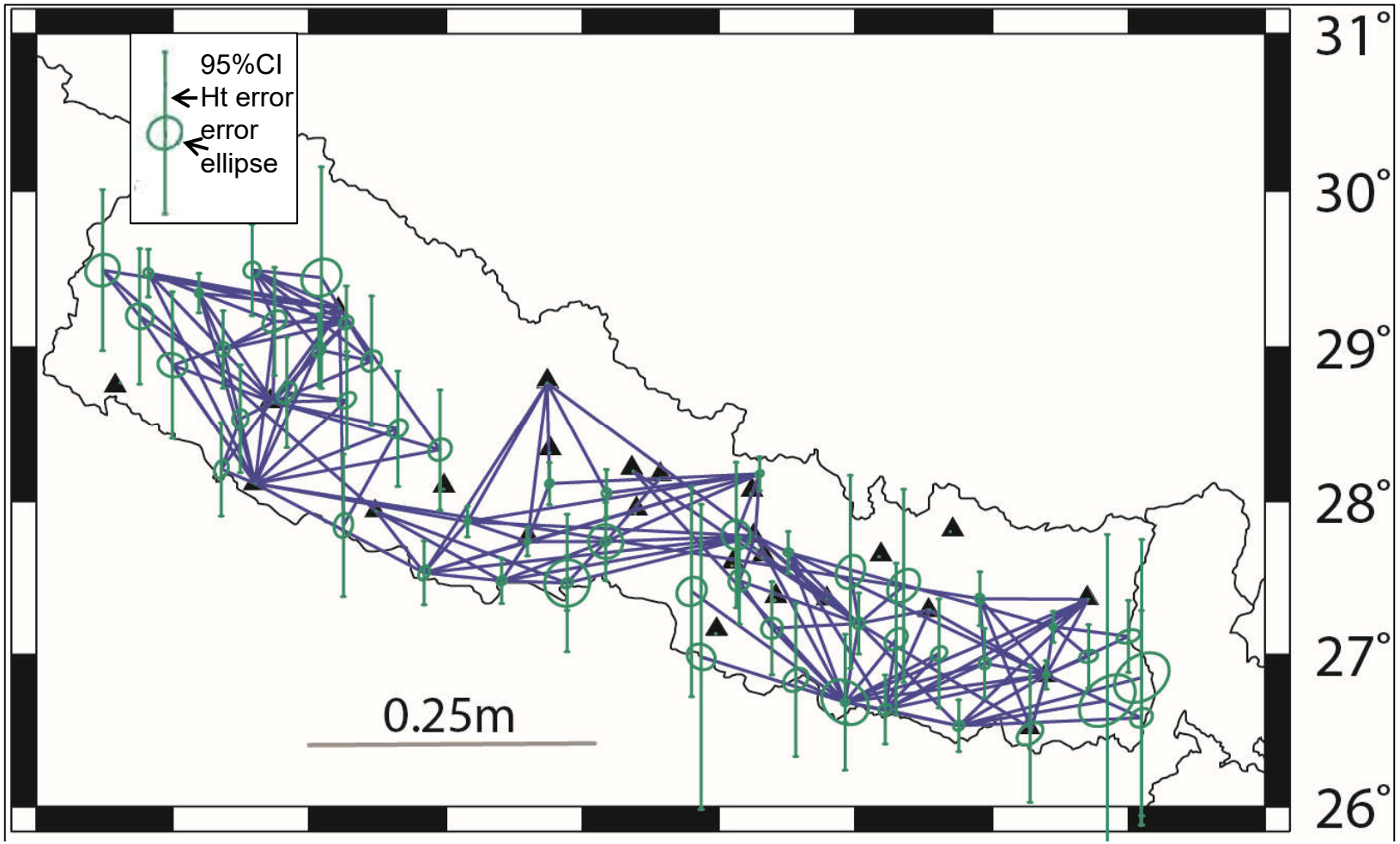
Control

- 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

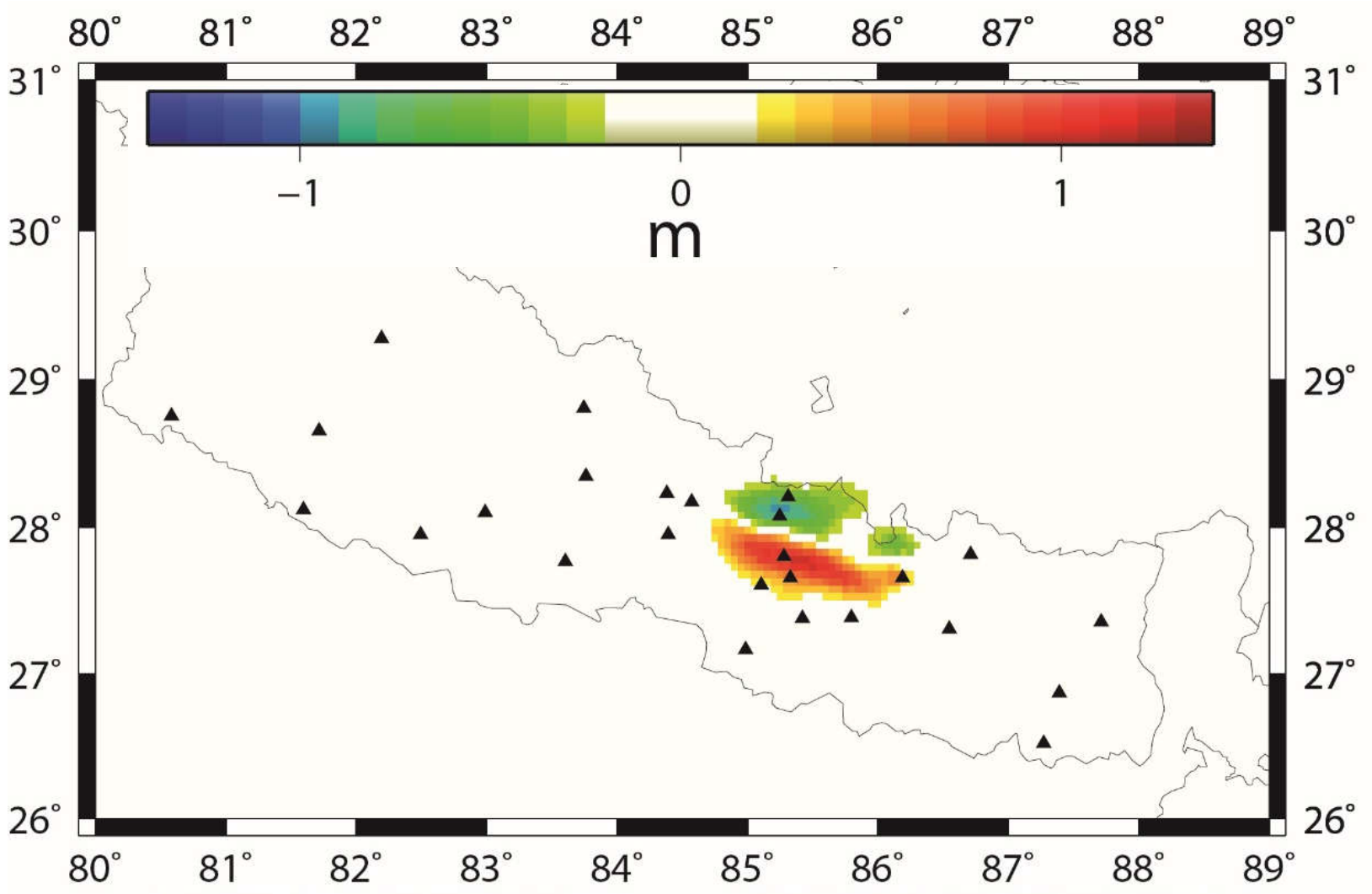


First Order adjustment Preliminary results

- 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

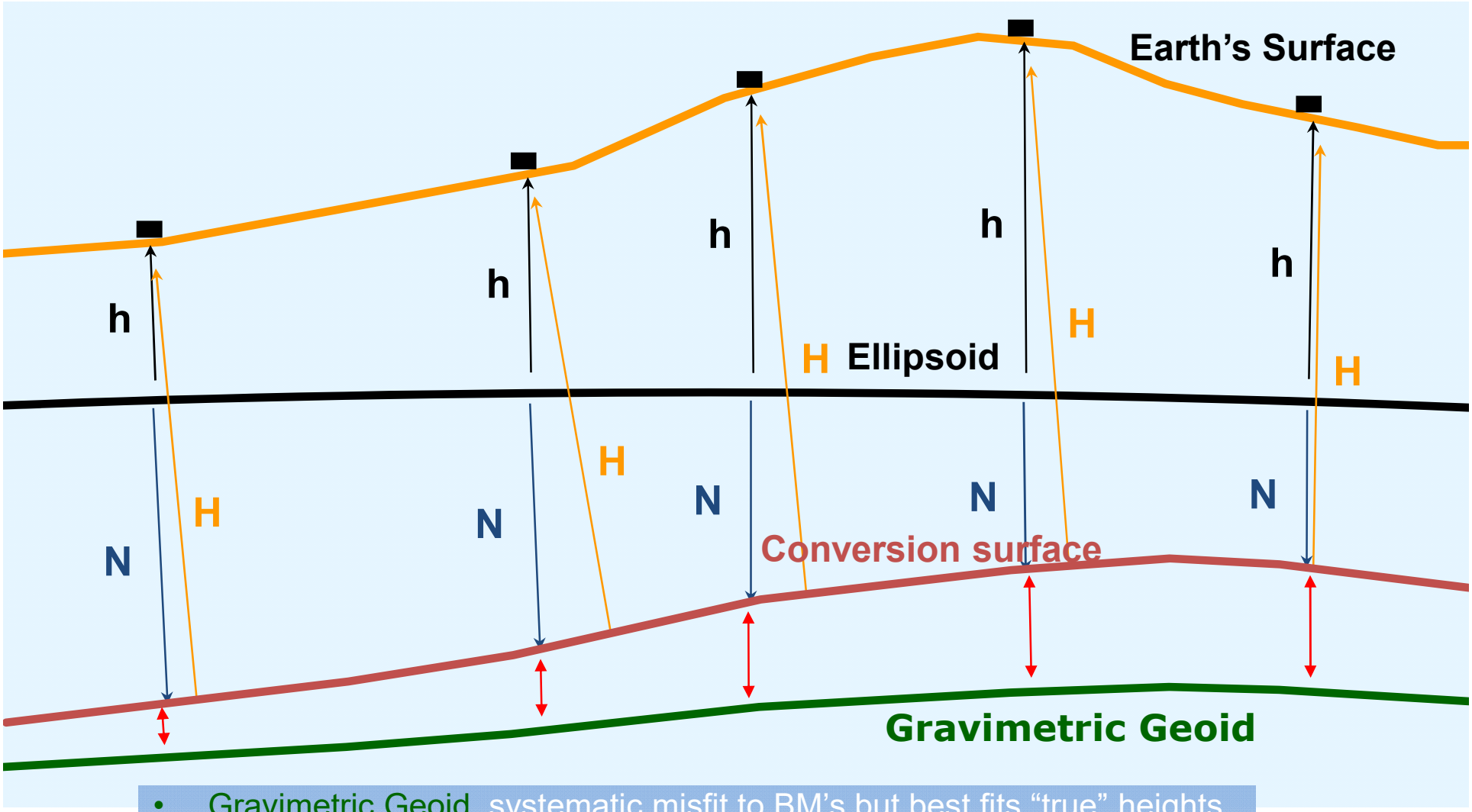


Heights Based on Geopotential Number (C)

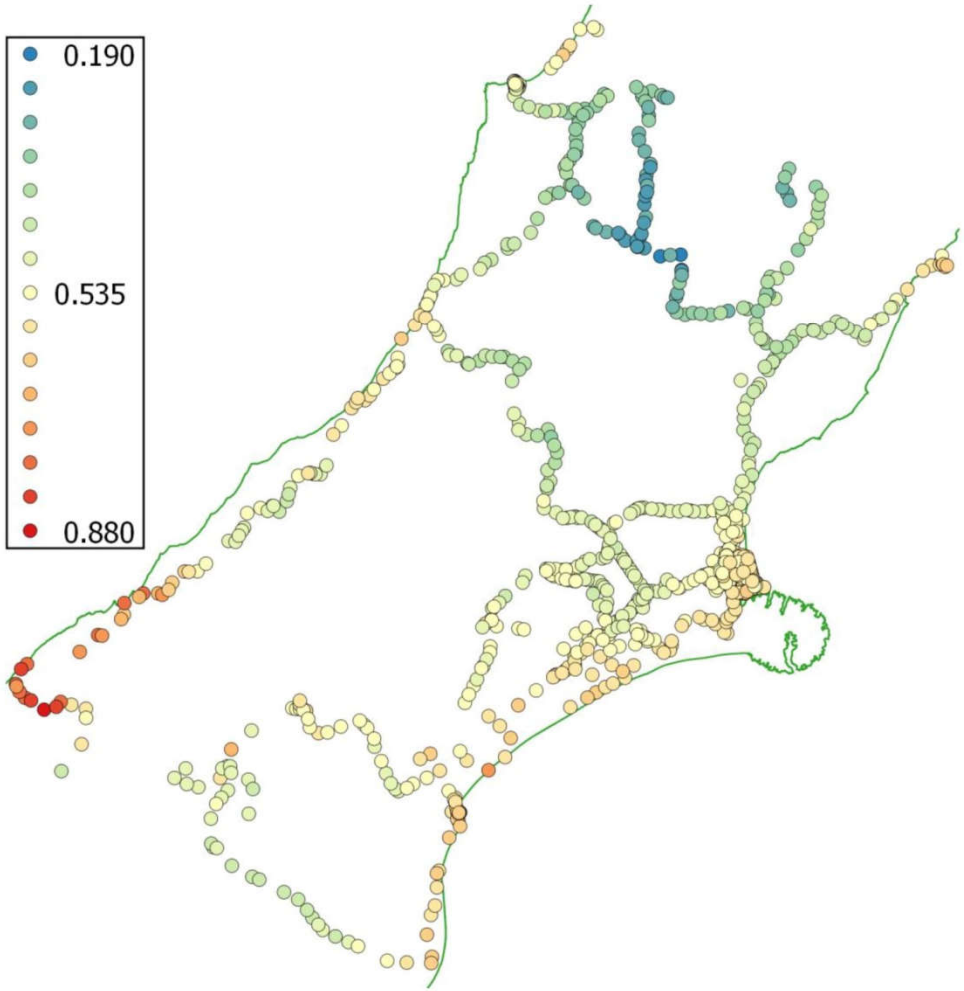
- **Normal Height (NGVD 29)** $H^* = C_N / \bar{\gamma}$
  - $\bar{\gamma}$ = Average normal gravity along plumb line
- **Dynamic Height (IGLD 55, 85)** $H^{dyn} = C / \gamma_{45}$
  - γ_{45} = Normal gravity at 45° latitude
- **Orthometric Height** $H = C / \bar{g}$
  - $\bar{g}$ = Average gravity along the plumb line

$$\Delta C_{b\text{-}a} = \sum_{a}^{b} \Delta h_i g_i$$

Geoid and Conversion Surfaces using GPS on BM data



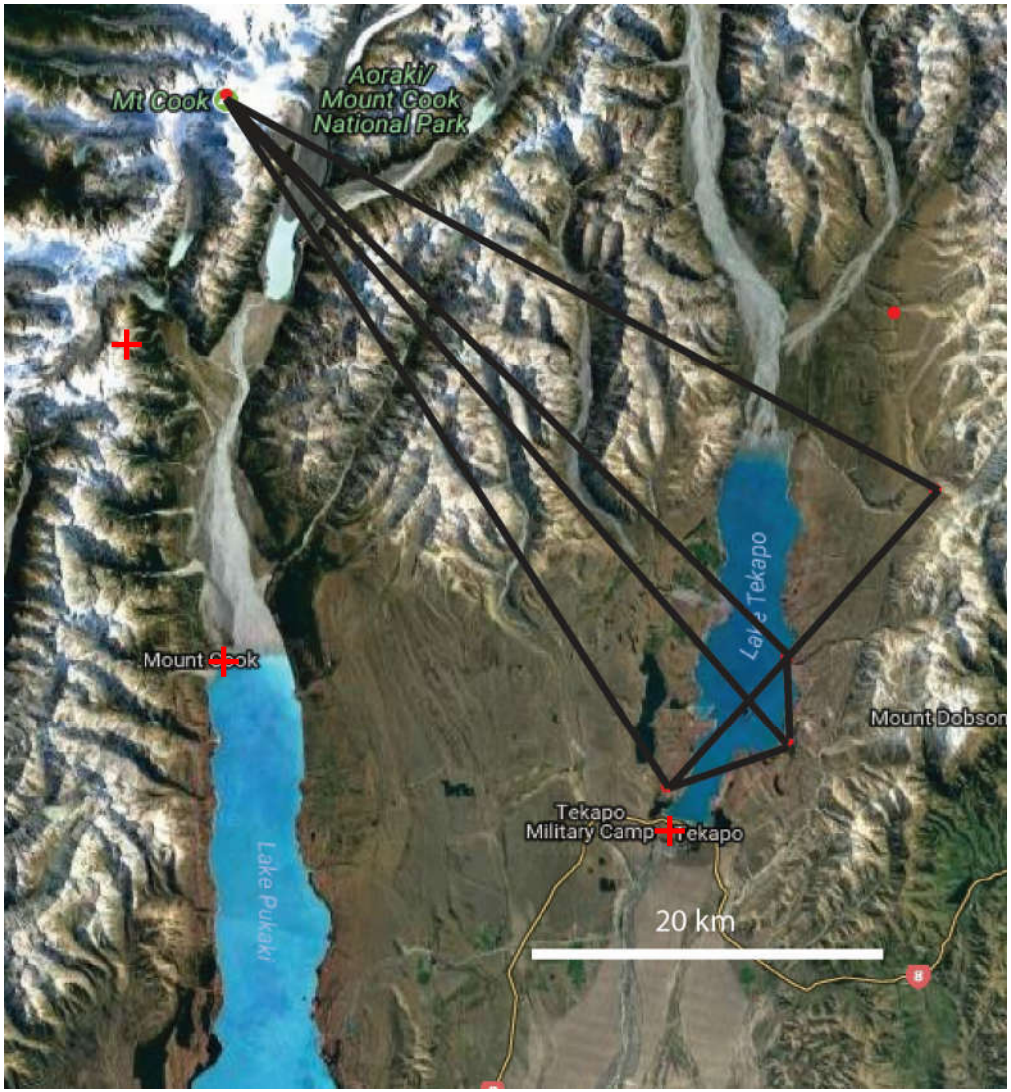
- Gravimetric Geoid systematic misfit to BM's but best fits "true" heights
- Conversion Surface model of systematic misfit derived from BM's



Land Information New Zealand
Toitū te whenua

Mean	0.5146
SD	0.09
Range	0.6903

Coefficient of Refraction	Calculated Ortho. Ht (95% C.I.)
k derived from reference lines	3703.31m*
Adjusted k= 0.075	3726.97m ± 1.38m
Adjusted k from measured T&P	3725.14± 1.38m



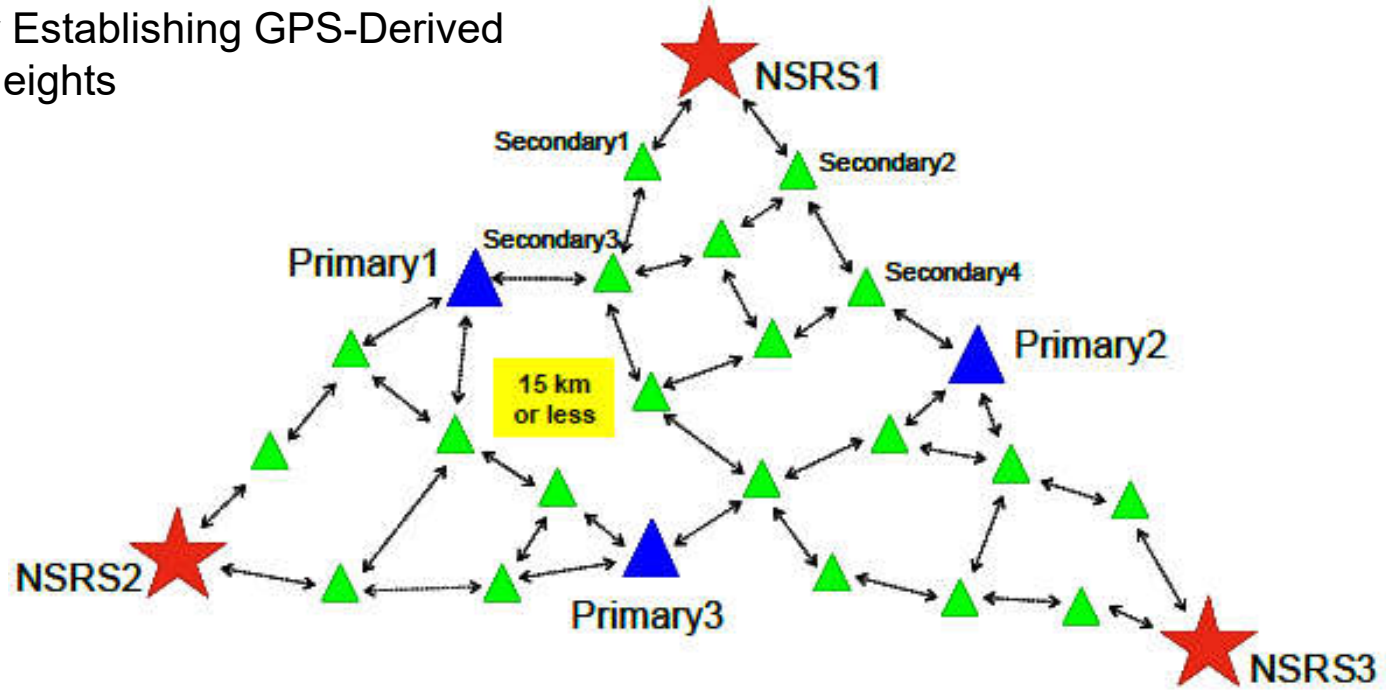
Accepted height =3724m

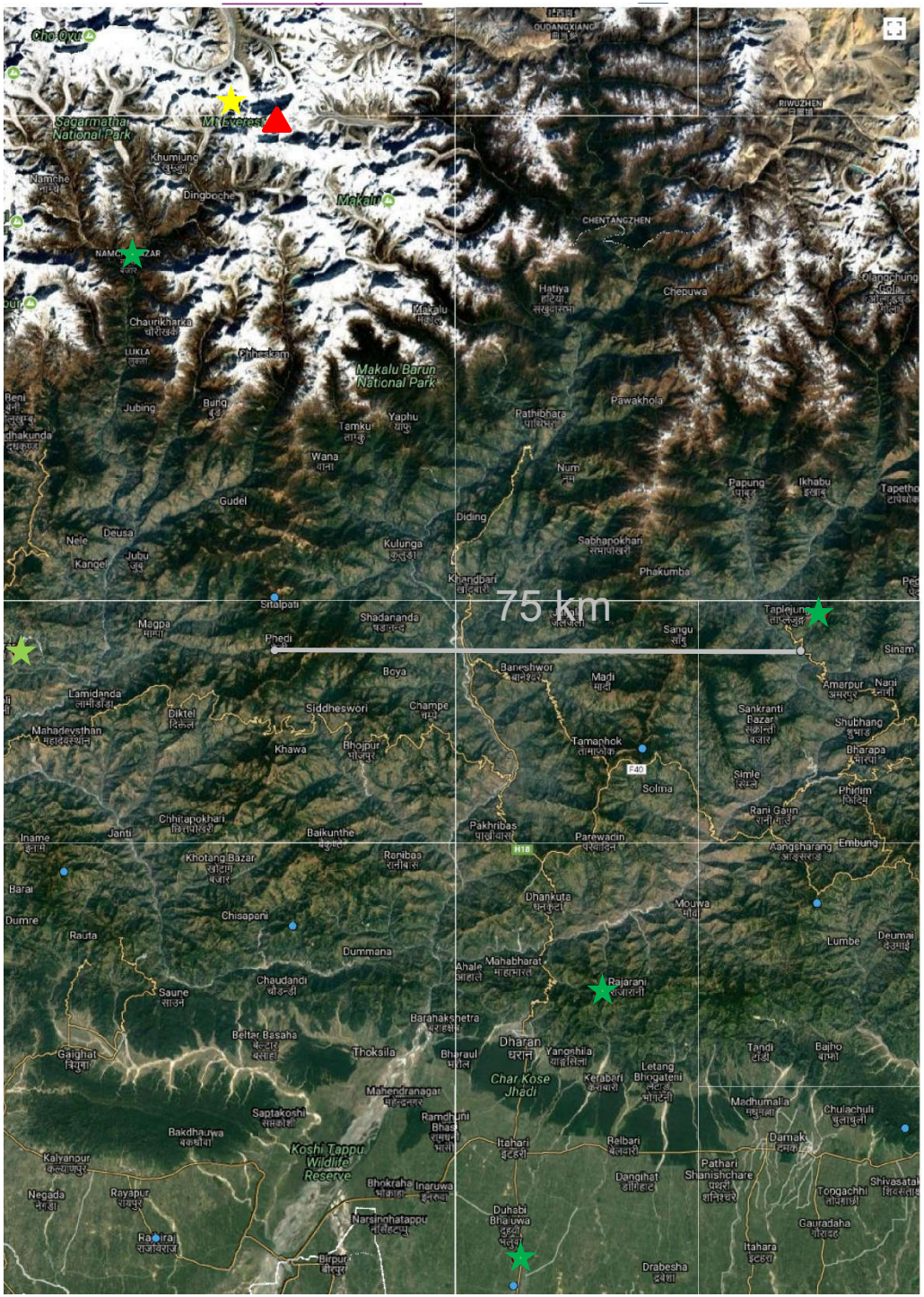
Tyler Hager
Summer Bursary Report
School of Surveying,
University of Otago,
Dunedin, New Zealand

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