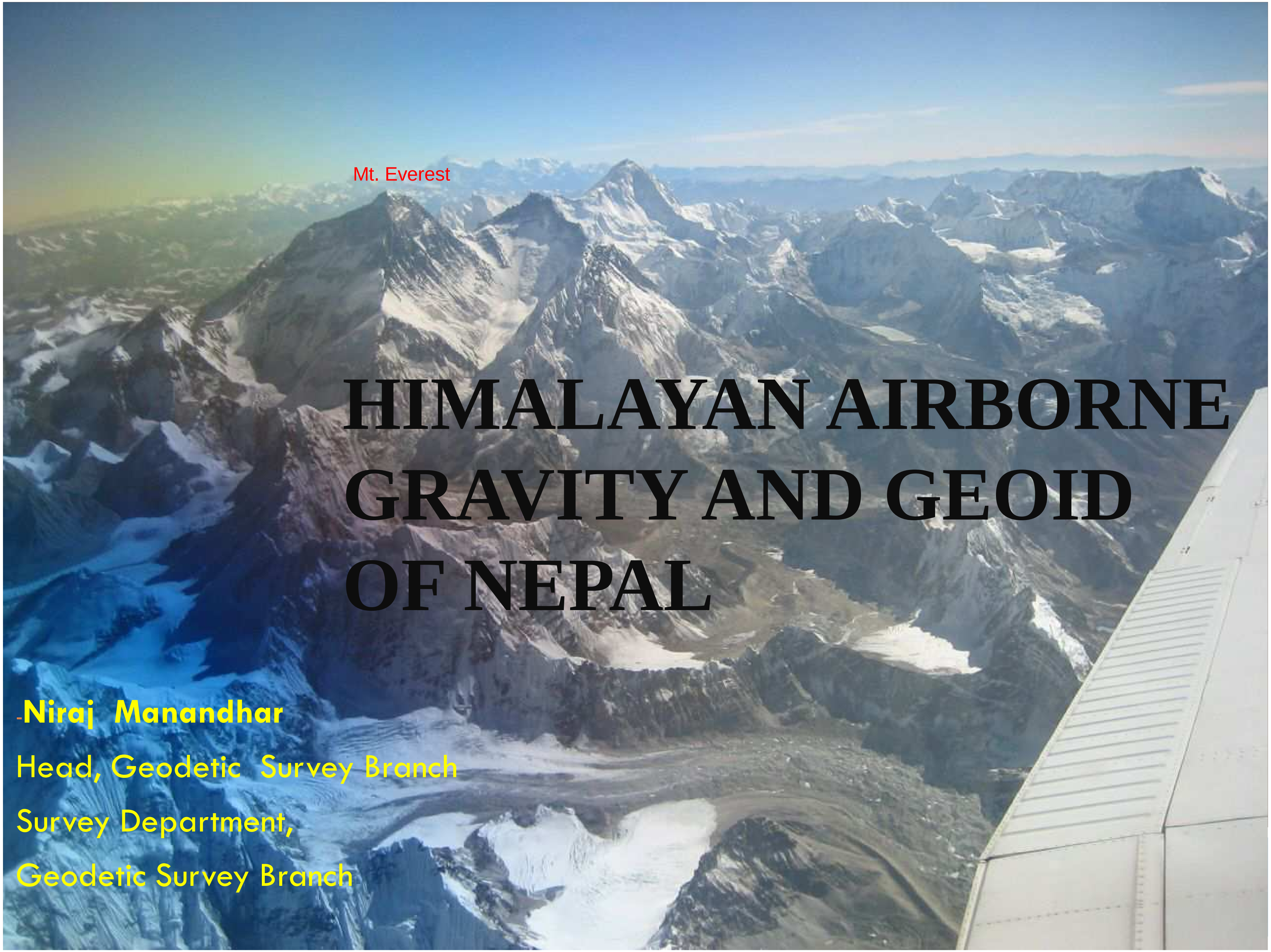

HIMALAYAN AIRBORNE GRAVITY AND GEOID OF NEPAL

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Survey Department,

Geodetic Survey Branch

Project Background

- Air Borne Gravity Survey Project was funded by National Space Institute (NSI), in cooperation with International Gravity Field service (IGFS) of International Association of Geodesy (IAG).
- SD (Survey Department of Nepal) and DTU(Denmark Technical University) jointly performed the Air Borne Gravity Survey of entire Nepal in December 2010.

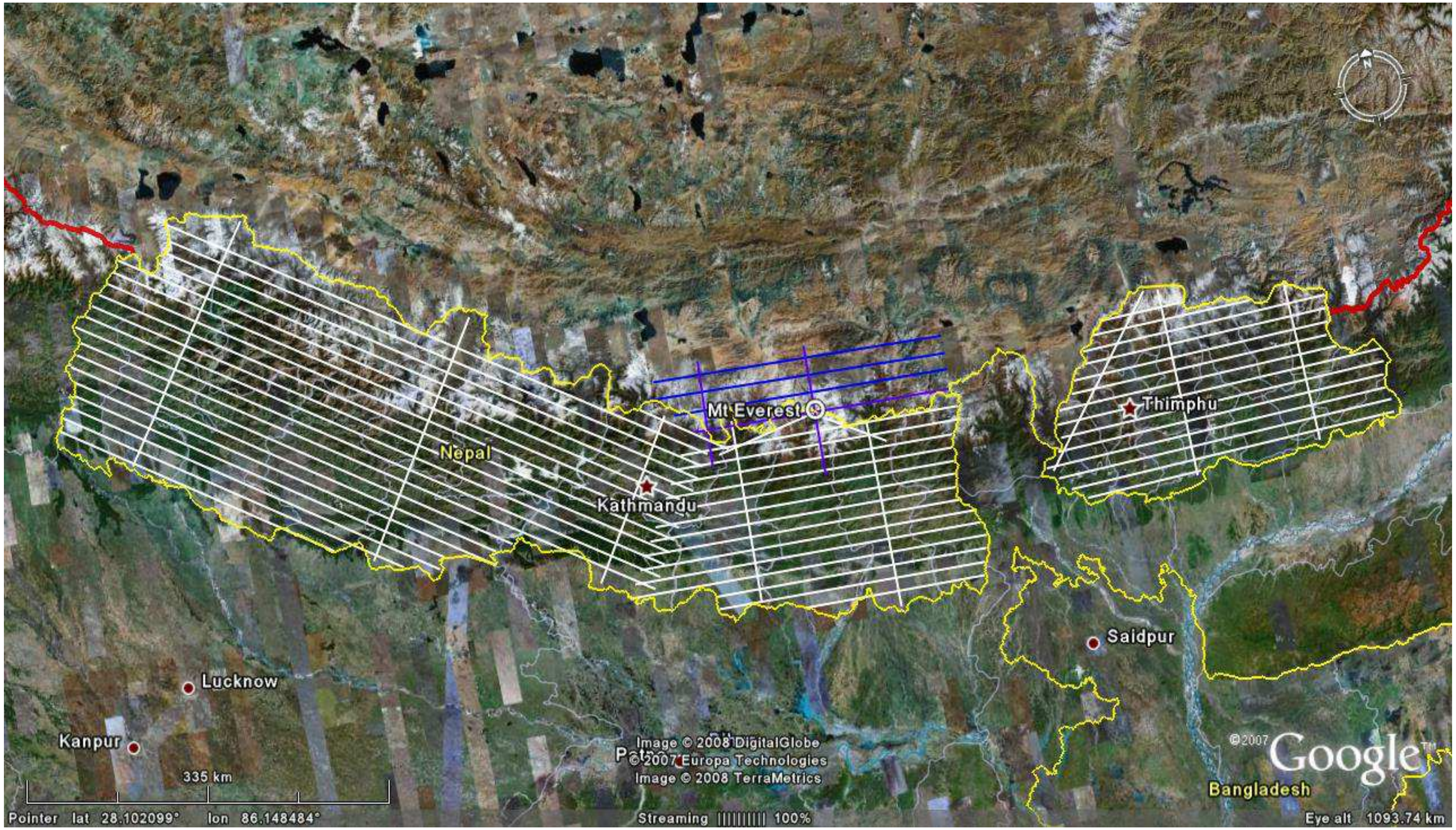
My presentation includes two parts;

- Airborne gravity observation
- Geoid determination of Nepal

Overview of Airborne Operation

- The survey was flown with COWI owned Beach Craft 200 OY-CKP.
- Aircraft arrived in Kath. on 27th Nov. 2011. Pilots went training in Kathmandu Flight Academy for 1 week in order to familiarize them with flight conditions in the mountains.
- Airborne gravity operation commenced on 4th of Dec. 2010. Last flight took place on 17th of Dec. Altogether 13 flights took place.

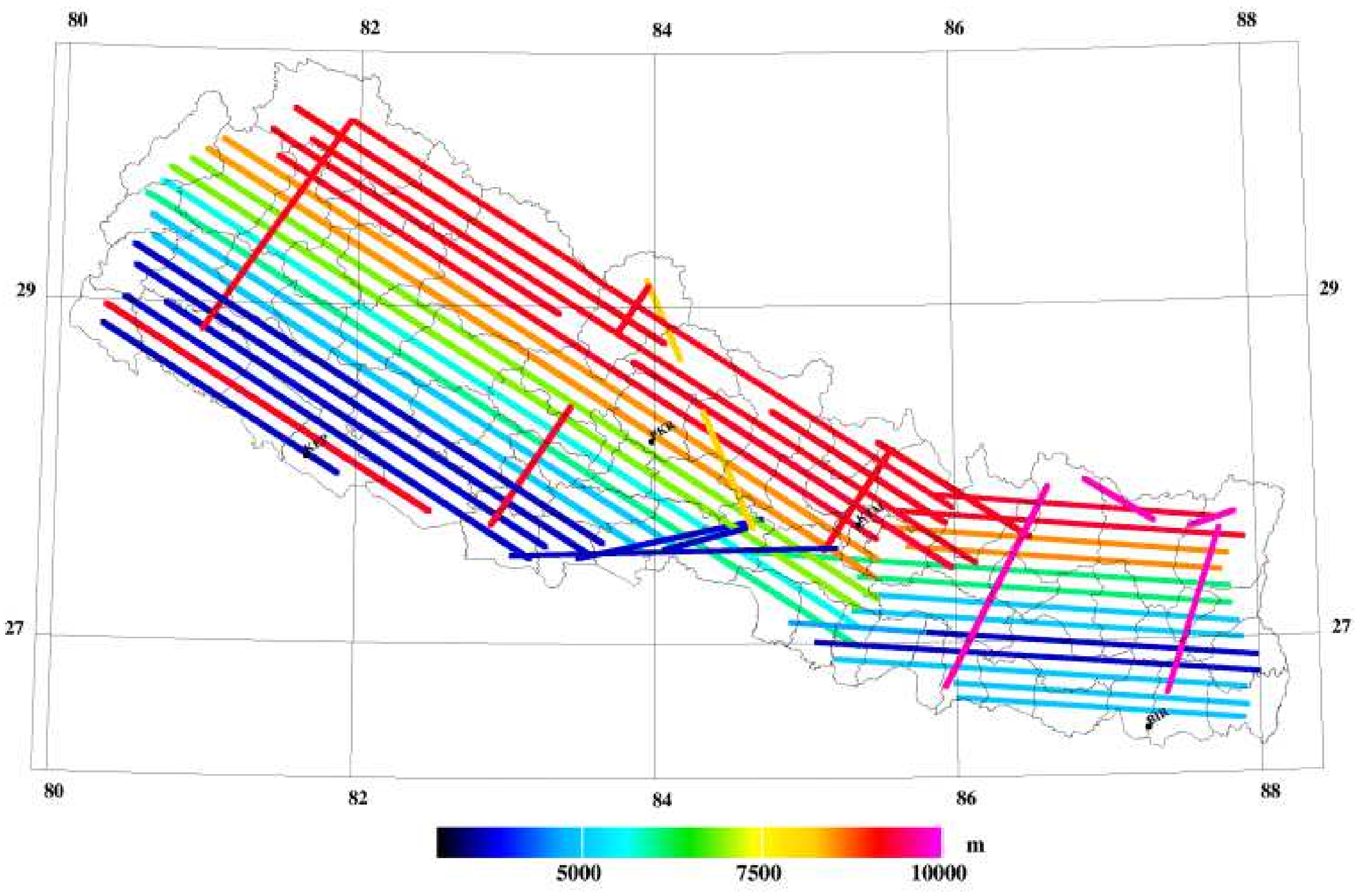
….Flight Details



…..Flight Details

- Turbulence and mountain winds were challenging when flying in mountainous area.
- Combination of high mountains and strong jet streams (100 + knots from WNW) made the flights a serious challenge.
- Despite these serious challenge acquisition of gravity data was successfully accomplished.

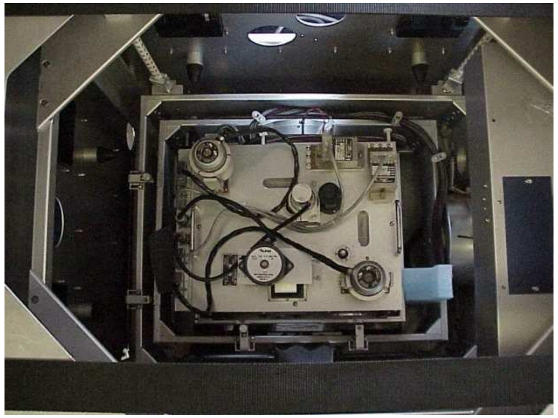
Flight Elevations



Survey Equipments Used

- The survey equipments installed consists of:
  - ✓ OY-CKP Beachcraft 200
  - ✓ LaCoste & Romberg Air/Sea gravimeter S-38
  - ✓ Chekan AM- 25 airborne gravimeter
  - ✓ Javad Lexon GPS receivers (aircraft)
  - ✓ Javad Delta GPS receivers (Aircraft and aircraft ground reference)

…..Equipments used



GPS Data Processing and Reference Station

- GPS reference station was referred to the station in Kathmandu Airport.

- GPS reference station co-ordinates were obtained by using AUSPOS GPS service provided by Geoscience Australia.

- Coordinate were given in ITRF 2005 frame.

- Aircraft Trajectories were computed with the waypoint software package from NovAtel (Calgary, Canada) using precise ephemerides from International GNSS service (http://igsb.ipl.nasa.gov).

Gravity Ties for airborne survey

- **Military Apron** reference gravity point was tied to three absolute gravity stations.
- KATHMANDU J (Airport), KATHMANDU AGB-2 (Survey Dept.), Absolute Gravity station (Nagarkot)
- LaCoste and Romberg G-meter serial no G-466 was used for these ties.

Airport	G- Value (IGSN71)	Sigma
TIA , Ktm., **Military Apron**	978 664.716 mGal	0.02

Airborne Gravity Processing

- Gravity results in this compilation are based solely on data from LaCoste & Romberg Gravimeter.
- Free-air gravity anomalies at aircraft level are obtained from:

$$\Delta g = f_z - f_{z0} - h^{''} + \delta g_{eotvos} + \delta g_{tilt} + g_0 - \gamma_0 - \left(\frac{\partial \gamma}{\partial h}(h-N) + \frac{\partial^2 \gamma}{\partial h^2}(h-N)^2\right)$$

where,

Δg	Free air gravity anomaly
f_z	Gravimeter observation
f_{z0}	Apron based gravimeter reading
δg_{eotvos}	Correction computed by the formula of Harlan
δg_{tilt}	Correction computed for tilt
g_0	Apron gravity Value
γ_0	Normal Gravity
N	Geoid undulation(EGM08)
h	GPS Ellipsoidal height
$h^{''}$	GPS vertical acceleration

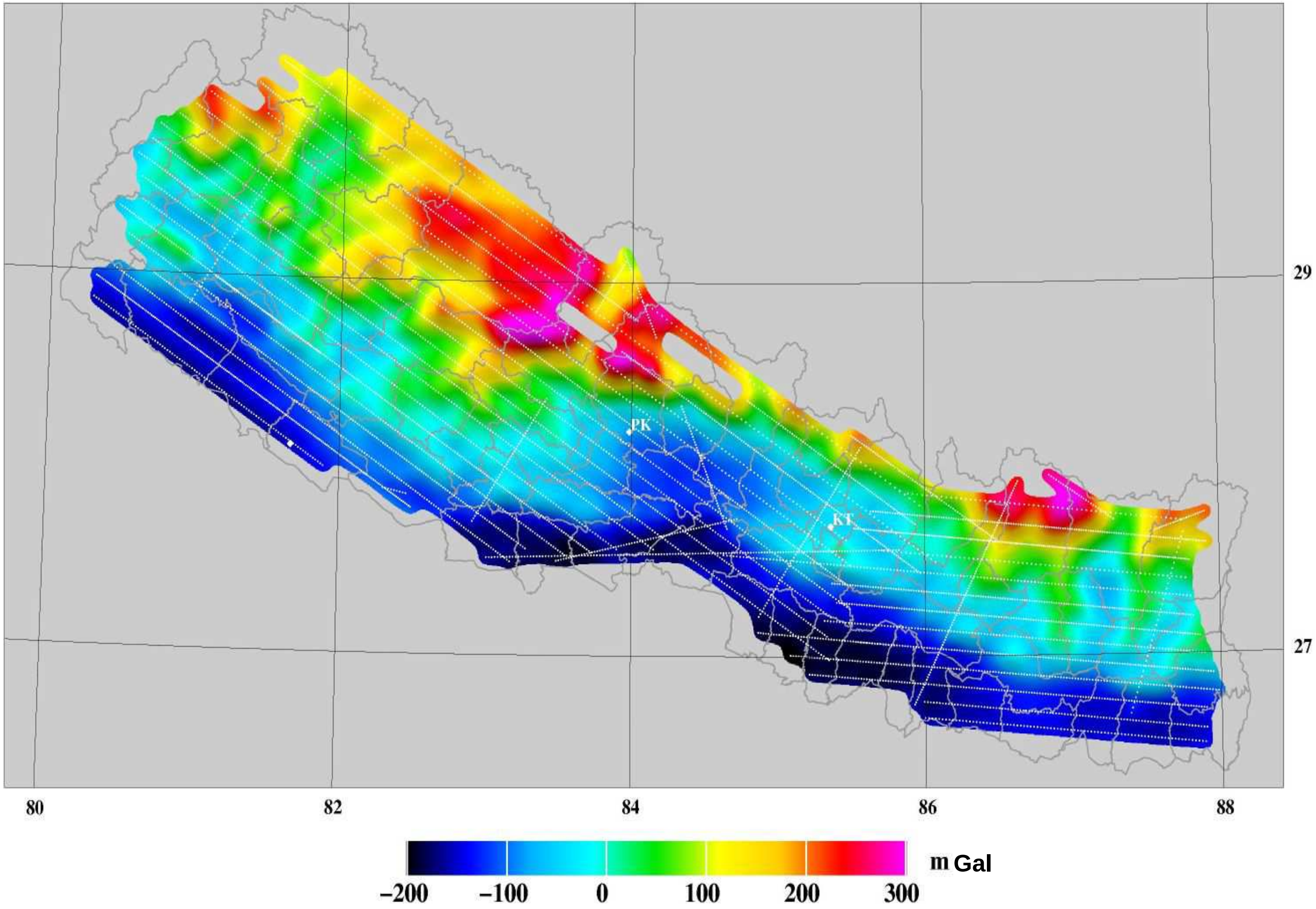
Data Validation

	Number of line crossings	RMS
Anomalies at the flight altitude	104	12.1m Gal
Anomalies reduced for terrain	104	7.3 m Gal
Anomalies reduced for terrain and downward continued to 6600m	104	4.6 m Gal

.....Data Validation

- Final dataset composed of 104 line intersections.
- Analysis of the misfit at the crossing point showed a RMS value of 12.1mGal.
- Misfit is mainly due to variation in altitude and many lines are as much as 5 km apart.
- RMS value reduces to 7.3 mGal after the effect of the terrain was removed and further reduces to 4.6 mGal when downward continued to a common level of 6600m.
- 4.6 mGal cross over error indicates a 3.2 mGal noise level on individual survey Lines.

Free air anomaly field at flight altitude



Summary

- Airborne gravity Survey was successfully completed in one of the most challenging settings in the world for airborne gravity measurement.
- The resulting free-air anomalies comes with an noise estimate of 3.2 mGal which is seen as very satisfactory given the challenging condition.
- There is little or no sign of internal biases in the dataset.

The next presentation is on

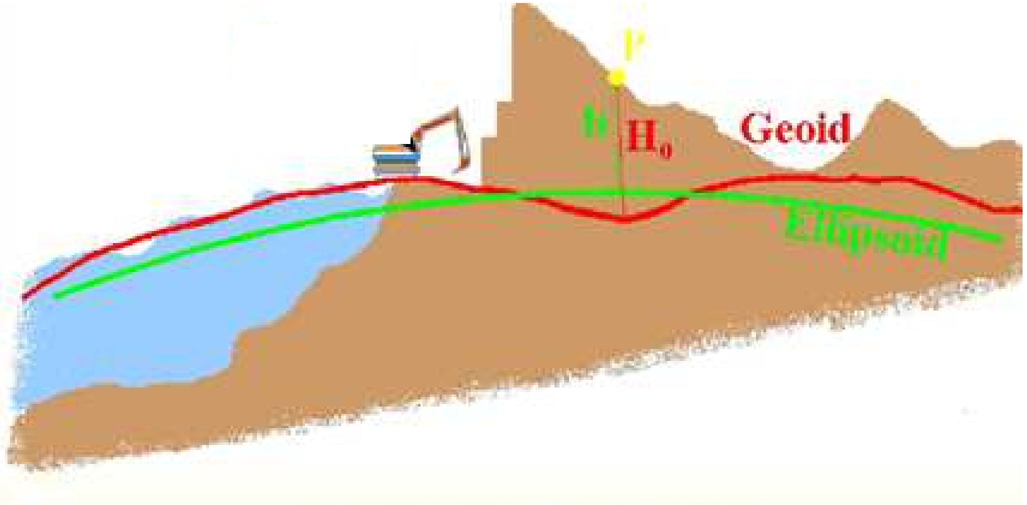
GEOID OF NEPAL FROM AIRBORNE GRAVITY SURVEY

What is Geoid?

- Only theoretical, we can neither see nor touch it.
- The natural extension of the Mean Sea Level surface under the land mass.
- The equipotential surface of the Earth's gravity field which best fits the global mean sea level.

…What is Geoid?

- Reference datum to which topographic heights are referred.



Digging an imaginary trench

- The geoid model is actually based on gravity data collected worldwide .

Why Geoid?

- we determine the elevation of any point with reference to the reference geoid at any time.
  - ✓ With the help of which we can complete the construction projects (that require elevation data) faster and in less cost.
  - ✓ Height of any prominent peaks can be determined accurately and solve the controversies.

…Why Geoid?

- Gravity data is not sufficient in this region . Due to this reason existing global geoid model do not provide the geoid information of required accuracy.

  So after the dense gravity observation the global geoid model will be improved.

Geoid Computation

- Concept is based on “remove-restore” technique
- Anomalous gravity potential ‘T’ is split into three parts:

where , $$T = T_{EGM} + T_{RTM} + T_{res}$$

- ✓ T_{EGM} = Anomalous gravity potential of a spherical hormonic model
- ✓ T_{RTM} = Anomalous gravity potential generated by Reisidual terrain model

High frequency part of topography computed by prism integration from SRTM height data

....Geoid Computaion

- ✓ T_{res} = residual anomalous gravity potential

  Potential corresponding to the unmodeled part of the residual gravity field. This part of the field is computed by spherical FFT

" The outcome of this technique is a gravimetric geoid, referring to a global datum: to adapt the geoid to fit the local vertical datum, and to minimise possible long- wave length geoid errors, a fitting of the geoid to GPS control is needed as the final geoid determination step."

In the context of Nepal……

- The method used is remove-restore, using EGM08 augmented with GOCE to degree 360 as reference and terrain effects from SRTM (15”).

- The software package GRAVSOFT was used for Geoid computations.

Airborne Data

- GRAVSOFT accepts the data format from airborne gravity data set file.
- Data set file contains following information;

  Point no, latitude , longitude, height,

  gravity (g),

  Free-air anomaly (Δg)

  and time (JD)

….Airborne data

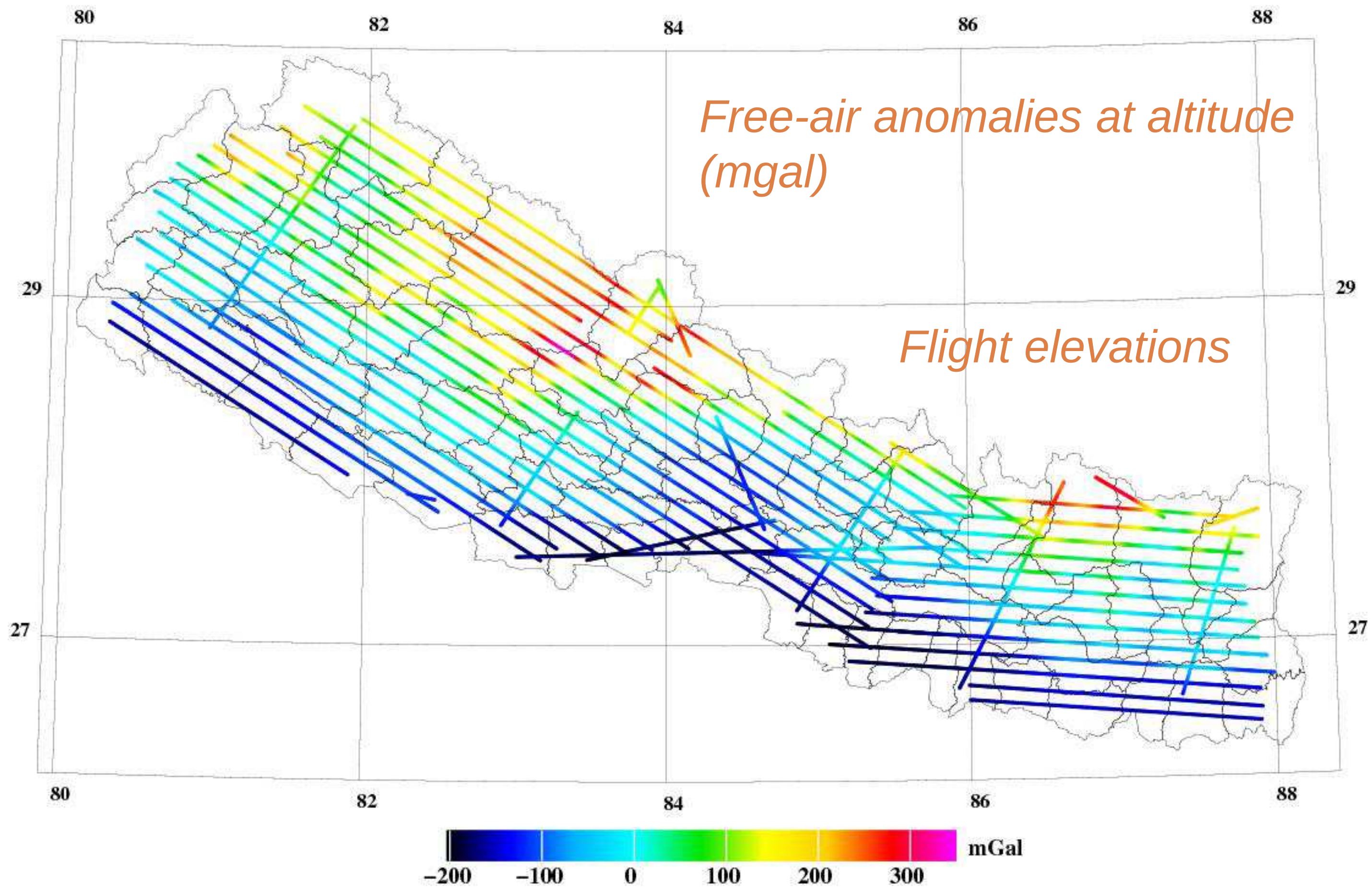


Fig. Free-air anomalies at altittude (10 sec spacing data)

....Airborne data

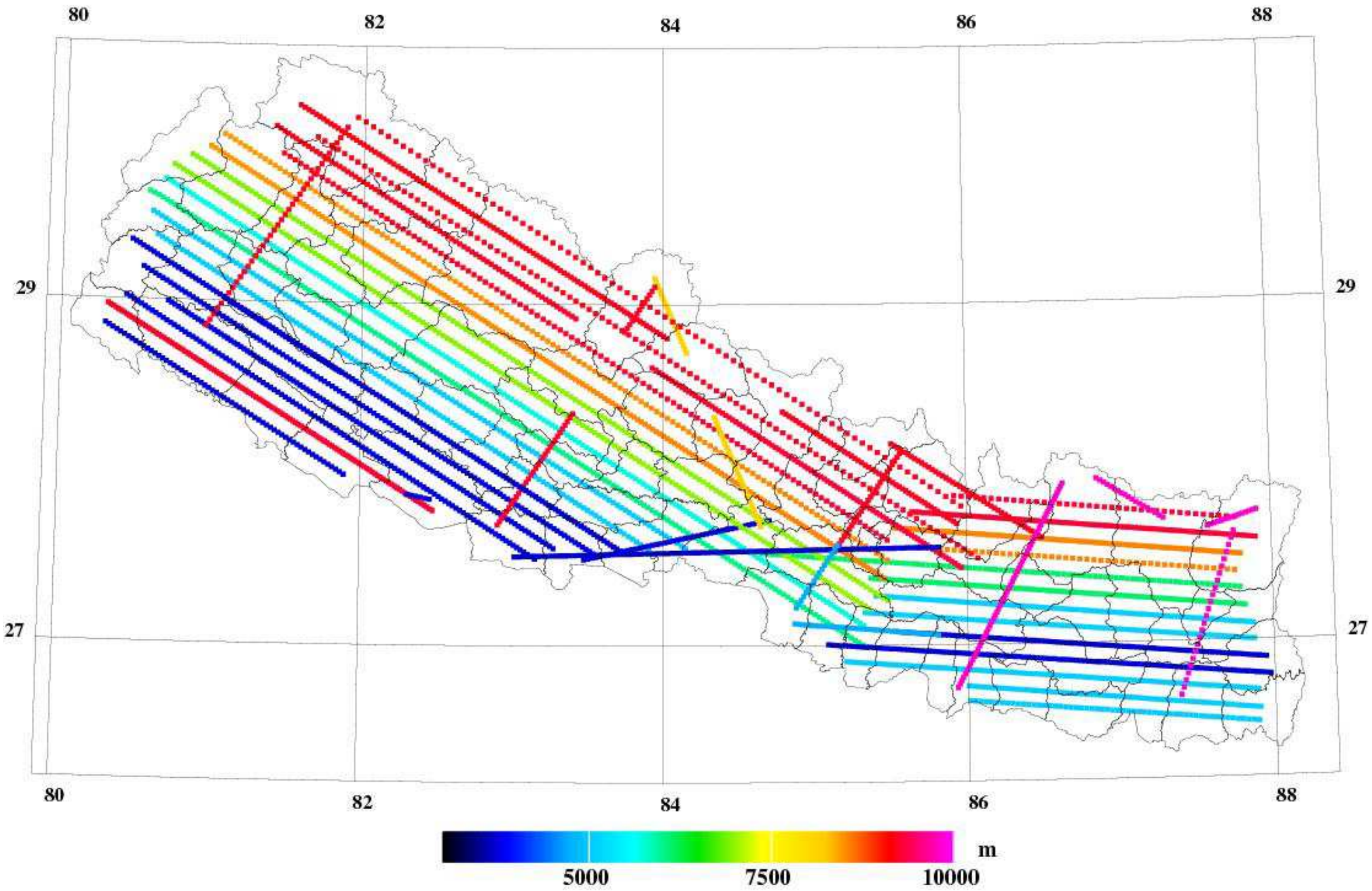


Fig. Height of flight tracks (30 sec spacing data)

EGM08/GOCE Computation

- EGM-GOCE gravity anomalies and height anomalies are computed in "sandwich grids" at 0 and 9 km elevation.
- We use here remove-restore with a maximal degree of 720; this provide a maximum utilization of possible valid EGM08 data in the China and India.
- An constant geoid bias of 53 cm has been added.

....EGM08/GOCE Computation

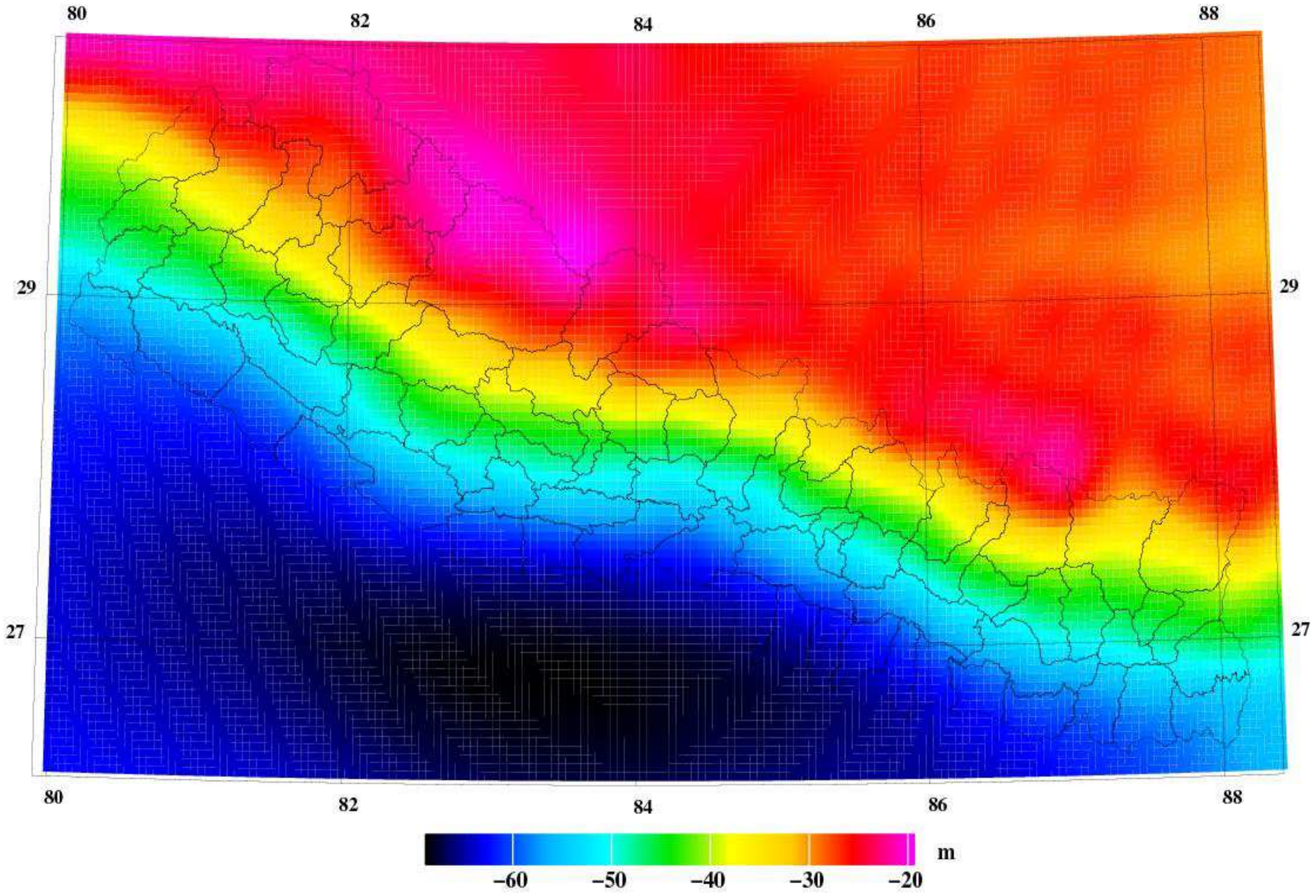


Fig. EGM08/GOCE reference quasigeoid (degree 720)

Land gravity data

Land gravity data used in geoid computations:

- 1st order gravity data (First order control points with g-values).
- Corrected Coordinated gravity data (Points in both low lands and mountains with a mix of GPS and levelled heights).
- BGI data (Mainly covering a profile from the Indian border through Kathmandu to Mt. Everest (Kano, 1974 data).
- Combined data set contains 1114 points.

Nepal Geoid

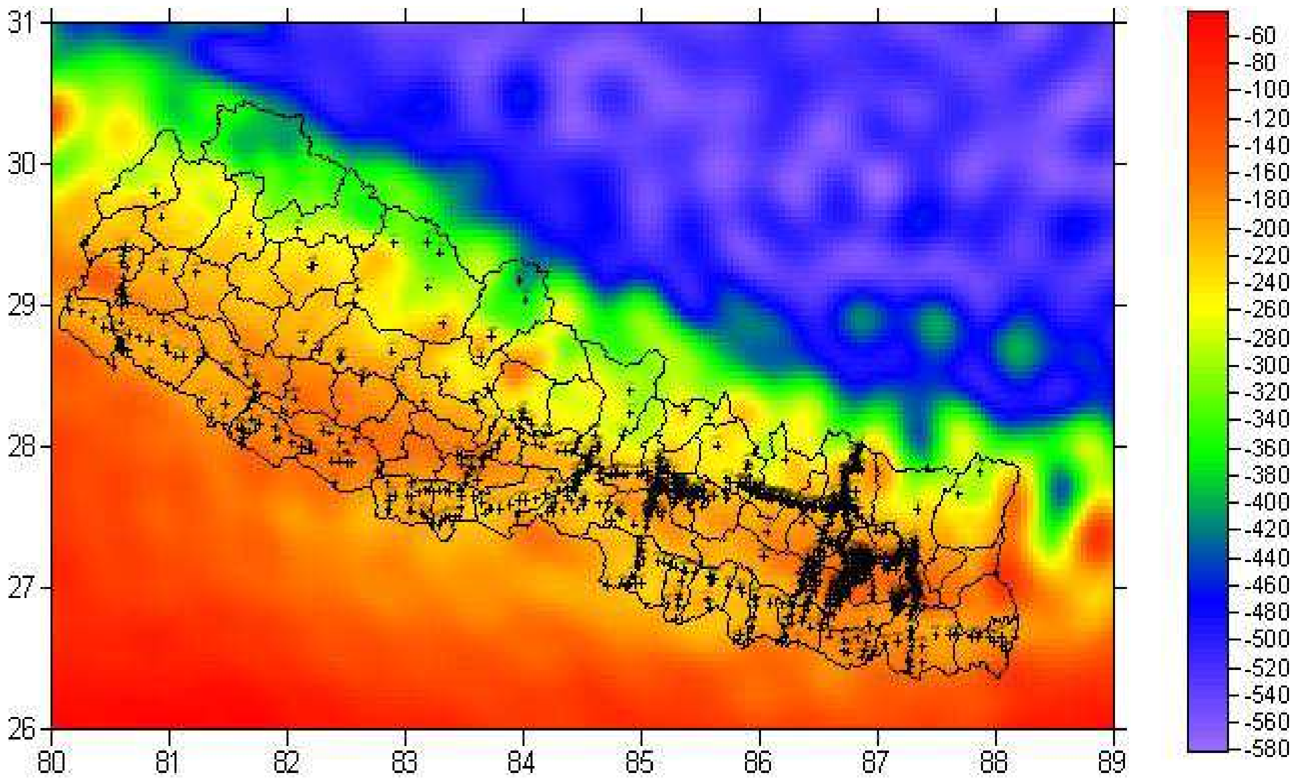


Fig. Bouguer anomalies in Nepal from airborne and EGM-GOCE, with location of surface data.

Geoid Determination

Geoid is obtained by following steps :

1. Downward continuation of airborne data from height to terrain level.
2. The downward continued gravity on the geoid is converted to quasi-geoid heights at terrain-level (ζ) by spherical FFT.
3. The terrain effects *n_rtm* are added.
4. EGM08 effects is added. This yields the quasigeoid at sea-level.
5. The final gravimetric geoid is thus obtain by adding the correction N-ζ* yielding the final "classical" geoid.

....Geoid Determination

- Based on above data the best geoid is calculated and given the name **(nepal_geoid_oct2011.gri).**
- It is accessible with user-friendly interpolation software (grid_int) along with GRAVSOFT software.

....Geoid Determination

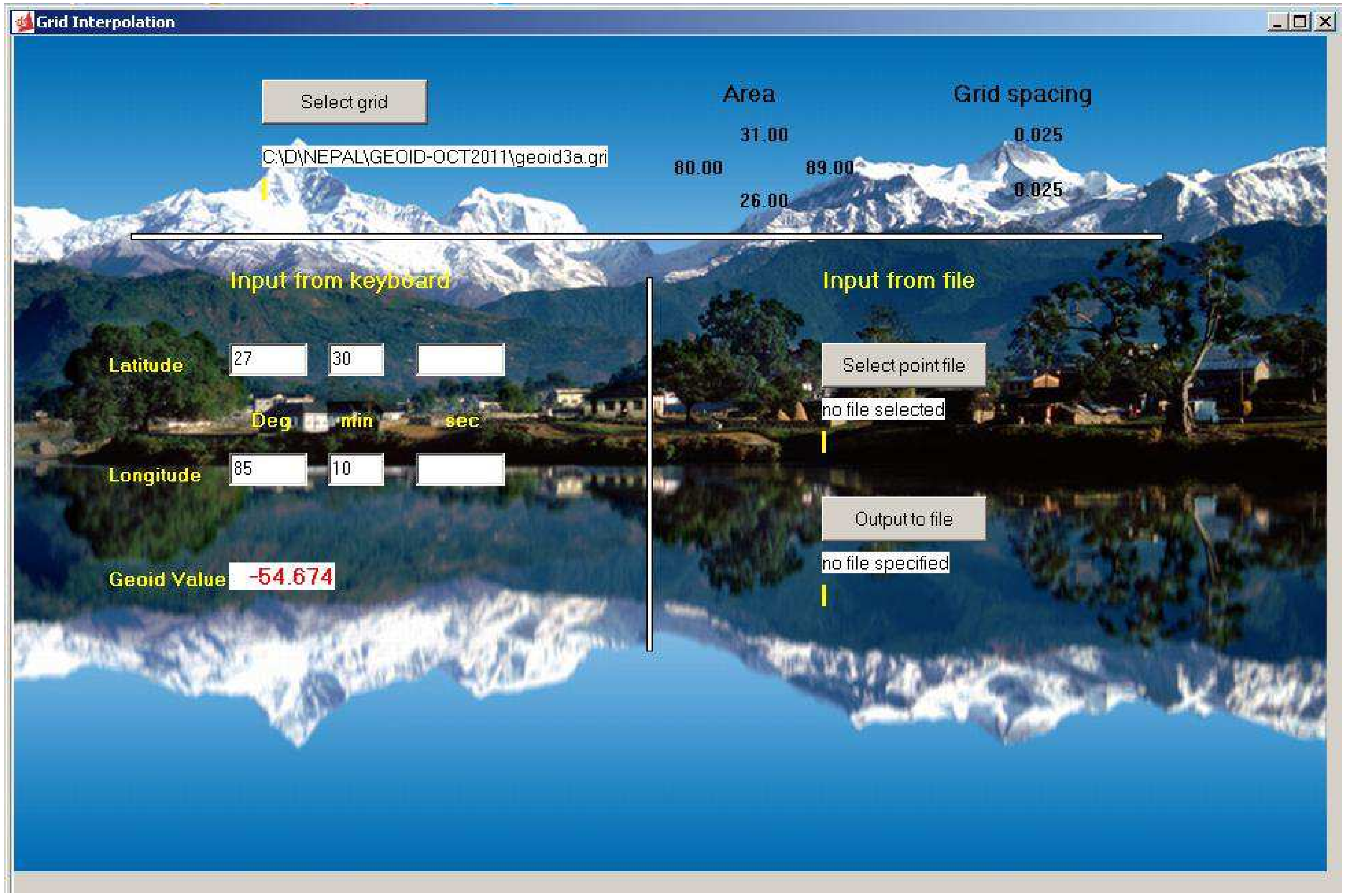


Fig. grid_int software interface

Summary of the Project

- Airborne Surveyed Data set of entire Nepal.
- Geoid computation interface
- **Preliminary Geoid: nepal_geoid_oct2011.gri** : needs some minor adjustments

Final geoid of Nepal

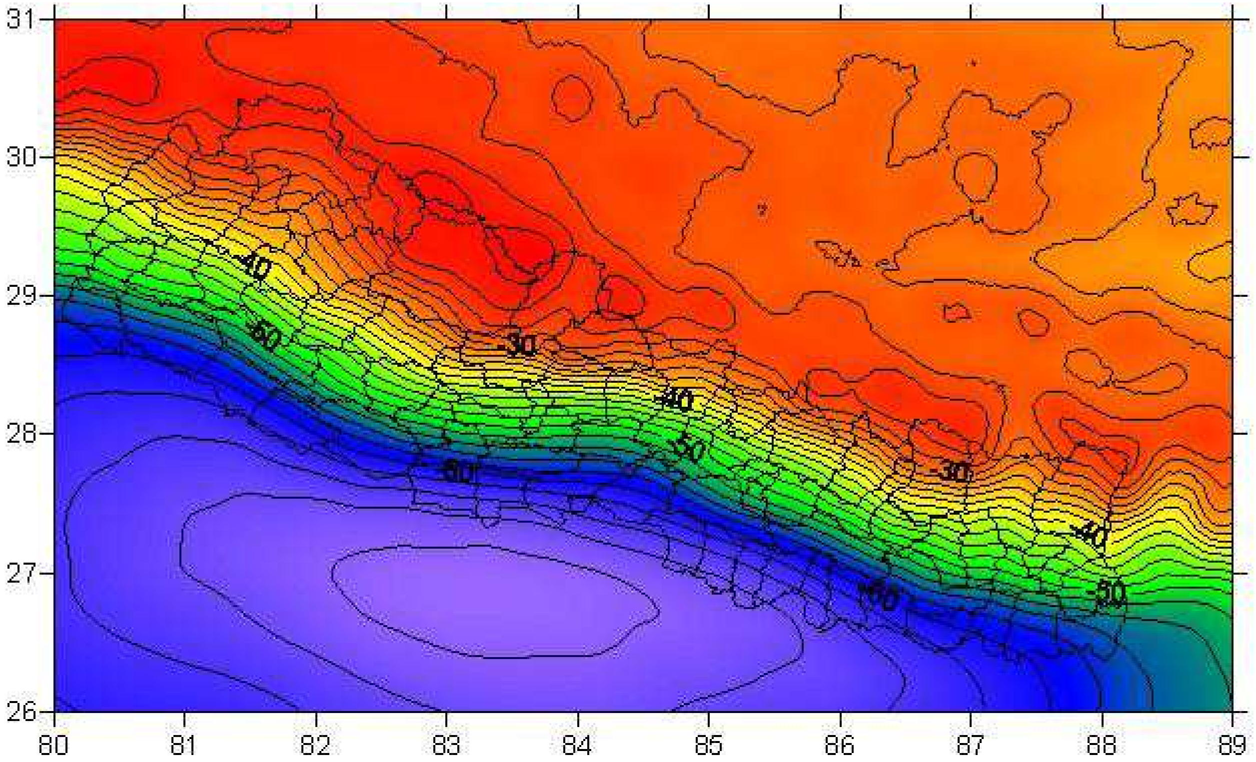


Fig. Final geoid of Nepal (2 m contours)

3D view of geoid of Nepal

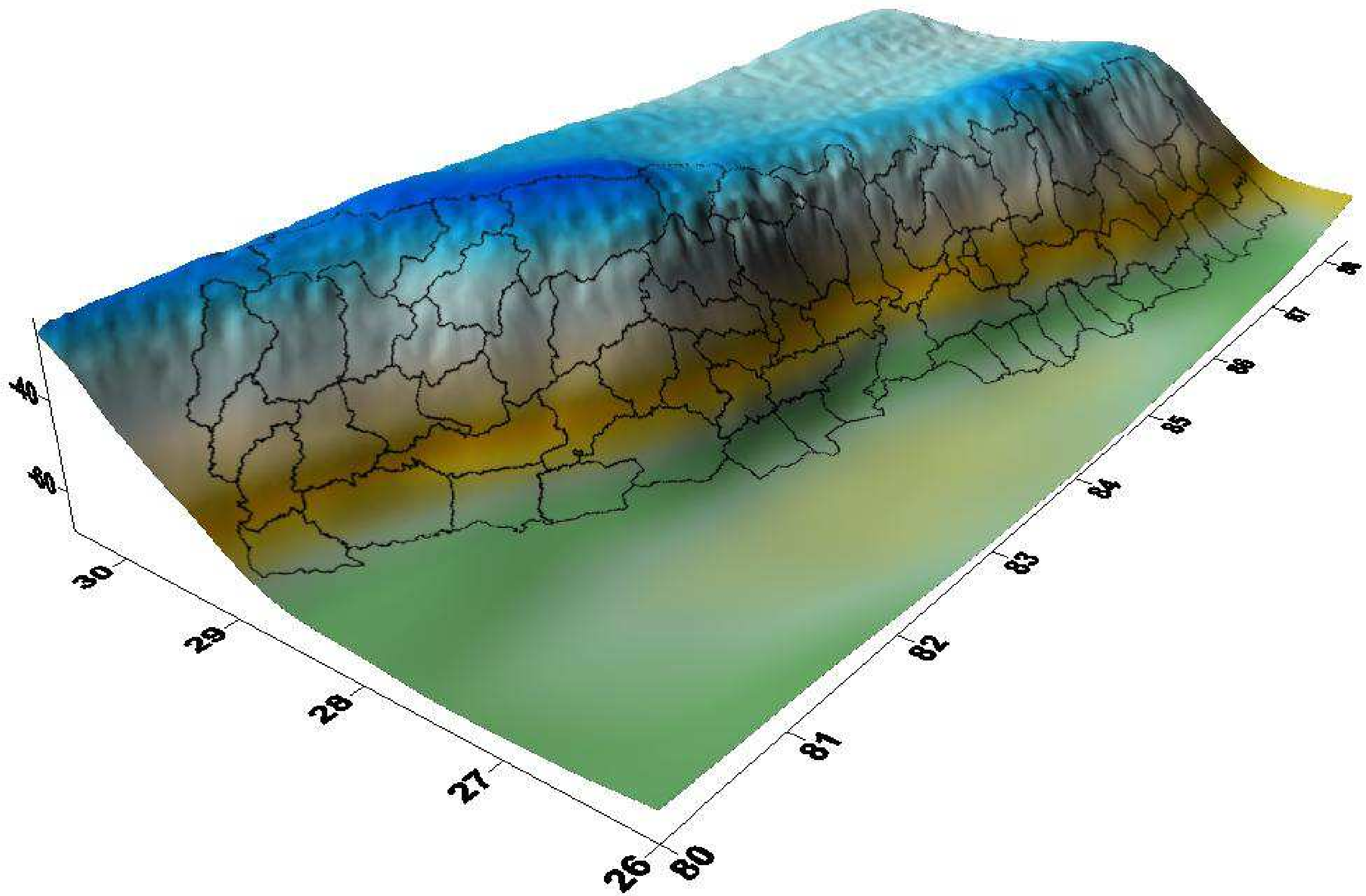


Fig. 3D view of geoid of Nepal.

Conclusion

- The Geoid information can serve not only for mapping, but also for scientific researches such as: earthquake prediction, geophysical changes and crustal deformation.
- A determination of Geoid create a precise reference vertical height datum.
- After the determination of geoid, GPS can be used to determine the physical height; without the conventional levelling method.

Mount Everest……

Mount Everest……

Mount Everest……

Mount Everest......

Thank You!