Geoid Computation Difficulties in the Pacific Northwest

by

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Issues arising in Pacific Northwest geoid computations:

- Terrain Corrections at NGS disagree with those at GSD(GC)

- Terrain may not properly be represented by 30" data

- DEMs are not properly referenced to a consistent vertical datum

- G96SSS agrees to decimeters with GPS/Benchmarks in PNW, but EGM96 (Bouguer corrected) disagrees to 1 meter with GPS/Benchmarks
Problem #1

TC differences, NGS vs GSD(GC)

1996 Study of Southern British Columbia
CANADIAN TERRAIN CORRECTIONS (Jan 93)
Attempts to reproduce

- 2 DTEDs:
  - TOPO30
  - New Canadian DTED 1995

- 5 Independent TC programs:
  - ftc.f (FFT, Milbert)
  - tc01.f (Flat top Prism, Milbert)
  - tc.f (Flat top Prism, Forsberg)
  - tcpts01.f (Flat top Prism, Veronneau)
  - triter4.f (Inclined top Prism, Rupert/Beach) ***

- 202 points in 50° - 51° N, 235.5° - 237.5°

*** = Not fully tested yet
TC DIFFERENCES
Jan93 (Can Database) MINUS Other TCs

<table>
<thead>
<tr>
<th></th>
<th>TOPO30</th>
<th>1995 Canadian DTED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ave</td>
<td>12 mgals</td>
<td>14 mgals</td>
</tr>
<tr>
<td>RMS</td>
<td>17 mgals</td>
<td>19 mgals</td>
</tr>
<tr>
<td>Min</td>
<td>-17 mgals</td>
<td>-12 mgals</td>
</tr>
<tr>
<td>Max</td>
<td>+45 mgals</td>
<td>+54 mgals</td>
</tr>
</tbody>
</table>

- 122 non-zero points
- Overall stats for all 4 fully-tested programs
- **Conclusion:** The Jan93 TCs (currently still in the Canadian database) are systematically higher than all 8 (4 programs, 2 DTEDs) TC sets at NGS, by a factor of 1.5 to 1.8
CANADIAN TERRAIN CORRECTIONS (Jan 93)  
Preliminary Results

- Unable to reproduce the January 1993 TC's

- Attempts using the old (TOPO30) DTED gave results closer to Jan 1993 than the new DTED

- FFT method agrees to within +/- 1 mgal with prism methods, except for large (>30 mgal) spikes, where the FFT is systematically too low by an average of 8 mgals

- Level 1 DTED (3"x6") unable to get Jan93 TCs!
Problem #2

30" DEM fails to capture full terrain signal

1996 Study of Southern British Columbia
Create Canadian TC’s from 30" and 3" data

Example point:

<table>
<thead>
<tr>
<th>TC(Canada DB, 95)</th>
<th>TC(Topo30)</th>
<th>TC(3&quot;x6&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(50.66067, 236.88400)</td>
<td>54.6 mgals</td>
<td>14.4</td>
</tr>
</tbody>
</table>

[This study will be re-investigated in August/September 1998]

- Certainly 30" Not good enough
- Even 3" seems inadequate
- Know sloped tops have 2-5 mgal effect near station
Problem #3

No vertical datum consistency in available DEMs

1997/98 DEM/DTED Study
Sources of 3" (or better) DEMs:

A) Most go back to 1960s/70s DMA 3" data
   - Old DMA data comes from 1:250,000 maps
     - 1:250,000 maps from old satellite sources
   - NIMA was updating cell by cell with new photo sources, but has nearly stopped recently
   ***NO vertical datum documentation or consistency

B) SRTM (expect new DTED in 2003)
   ***Vertical datum could be consistent!

C) USGS is digitizing 1:24,000 maps onto 10 and 30 meter UTM grids (90% of west US done, 30% of East US done)
   ***Vertical datum well defined as NGVD29
DEM Differences
DMA 1998 DTED minus USGS 3"
(44° to 49° N, 237° to 243° E)

RED = +25 m or greater differences
MAGENTA = -25 m or lower differences
Geoid Undulation changes due to random ±200 meter error in one 1°x1° DEM (of 2’x2’ elevations)

Red = +1 cm or greater change
Magenta = -1 cm or lower change
Geoid Undulation changes due to systematic +20 meter error in one $1^\circ \times 1^\circ$ DEM (of 2’x2’ elevations)

Red = +1 cm or greater change
Magenta = -1 cm or lower change
Problem #4

EGM96 bust in Pacific Northwest

1996/97 GEOID96 computation and validation
G96SSS minus EGM96 (Bouguer Corrected)

Red = +1.5 meters and greater differences
Magenta = -1.5 meters and lesser differences
EGM96 and G96SSS vs. GPS on Benchmarks

- Compared both models to ITRF94/NAVD88 data

- National average residuals of:
  - EGM96/GPS/BM: +41 cm
  - G96SSS/GPS/BM: +43 cm

In PNW (44°-49°, 237°-243°), with average removed:
  - EGM96/GPS/BM: +94 cm ± 28 cm
  - G96SSS/GPS/BM: -12 cm ± 19 cm
GPS/BM/G96SSS residuals (about 43 cm ave)
CONCLUSIONS

- Most geoid research effort is concentrating on the Pacific Northwest

- Many problems stem directly from unreliable high resolution DEMs

- GPS on Benchmarks provide a useful independent check on geoid models

- Additional research being done on downward continuation and long wavelength terrain effects