

# **Geoid Computation Difficulties in the Pacific Northwest**

by

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## Issues arising in Pacific Northwest geoid computations:

- 1996 - Terrain Corrections at NGS disagree with those at GSD(GC)
- Terrain may not properly be represented by 30" data ↑  
Spin off
- 98 - DEMs are not properly referenced to a consistent vertical datum
- 98 - 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

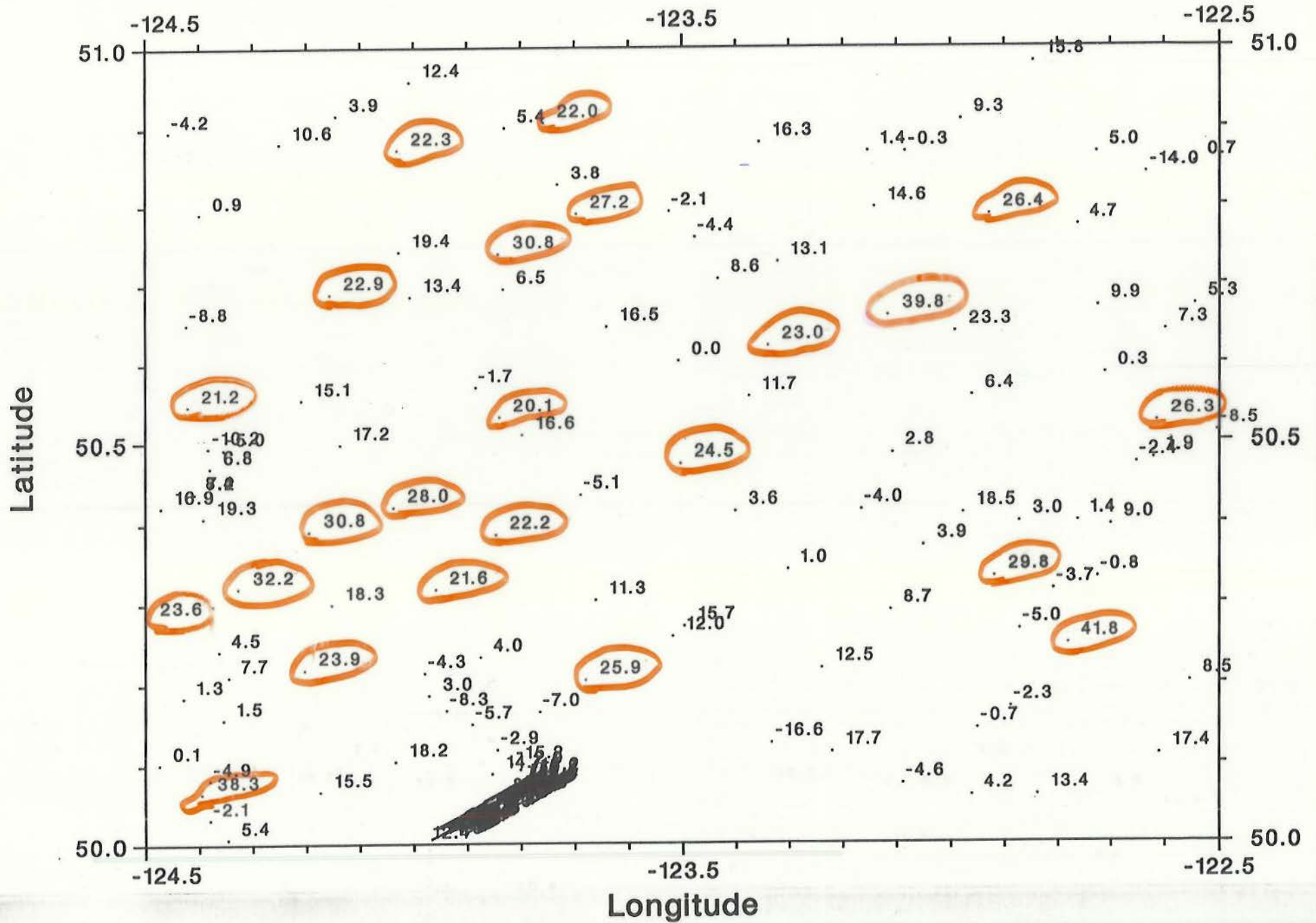
### Jan93(Can Database) MINUS Other TCs

	<u>TOPO30</u>	<u>1995 Canadian DTED</u>
<b>Ave</b>	<b>12 mgals</b>	<b>14 mgals</b>
<b>RMS</b>	<b>17 mgals</b>	<b>19 mgals</b>
<b>Min</b>	<b>-17 mgals</b>	<b>-12 mgals</b>
<b>Max</b>	<b>+45 mgals</b>	<b>+54 mgals</b>

- 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



# TC(Jan93) Minus TC(TOPO30/Prism/200km)



# 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!

ok in smooth areas

Next top

## 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:

	<u>TC(Canada DB, 95)</u>	<u>TC(Topo30)</u>	<u>TC(3"x6")</u>
(50.66067, 236.88400)	54.6 mgals	14.4	26.0

[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)

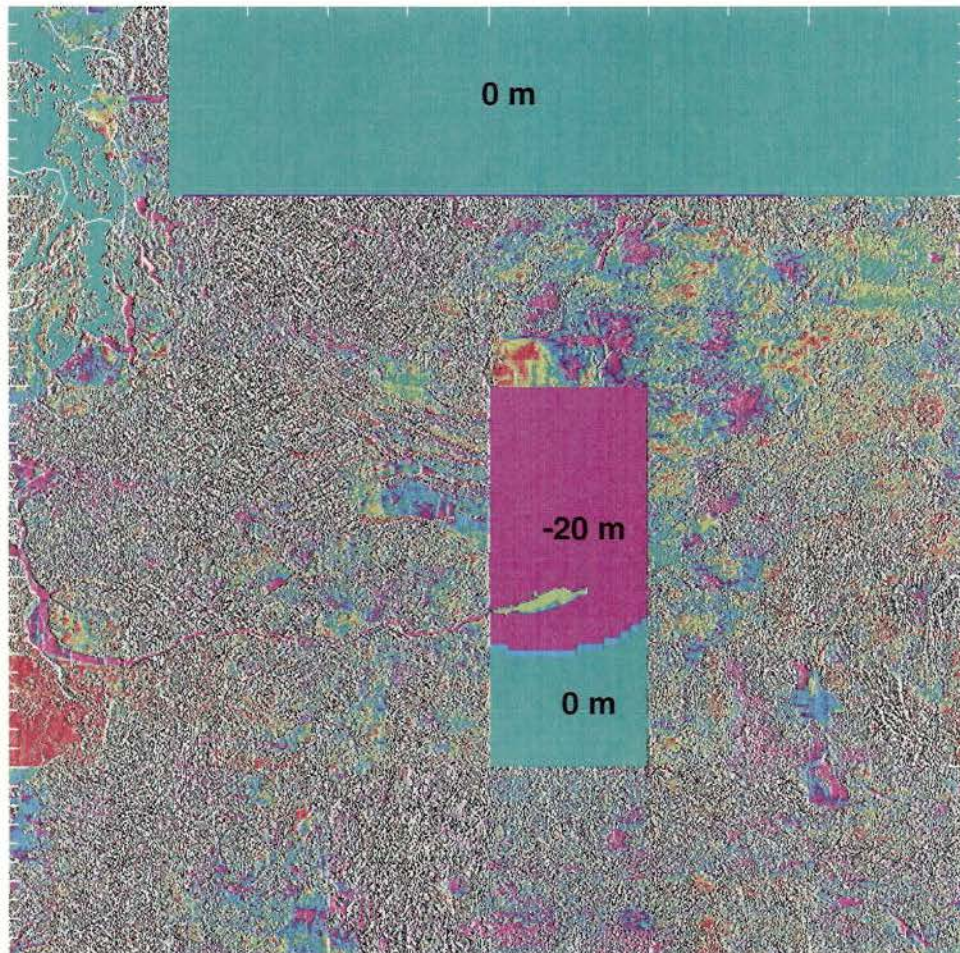
\*\*\*Vertical datum well defined as NGVD29

↳ prob: Edge matched "seamless" Db  
is univariable + SDTS transfer



# DEM Differences

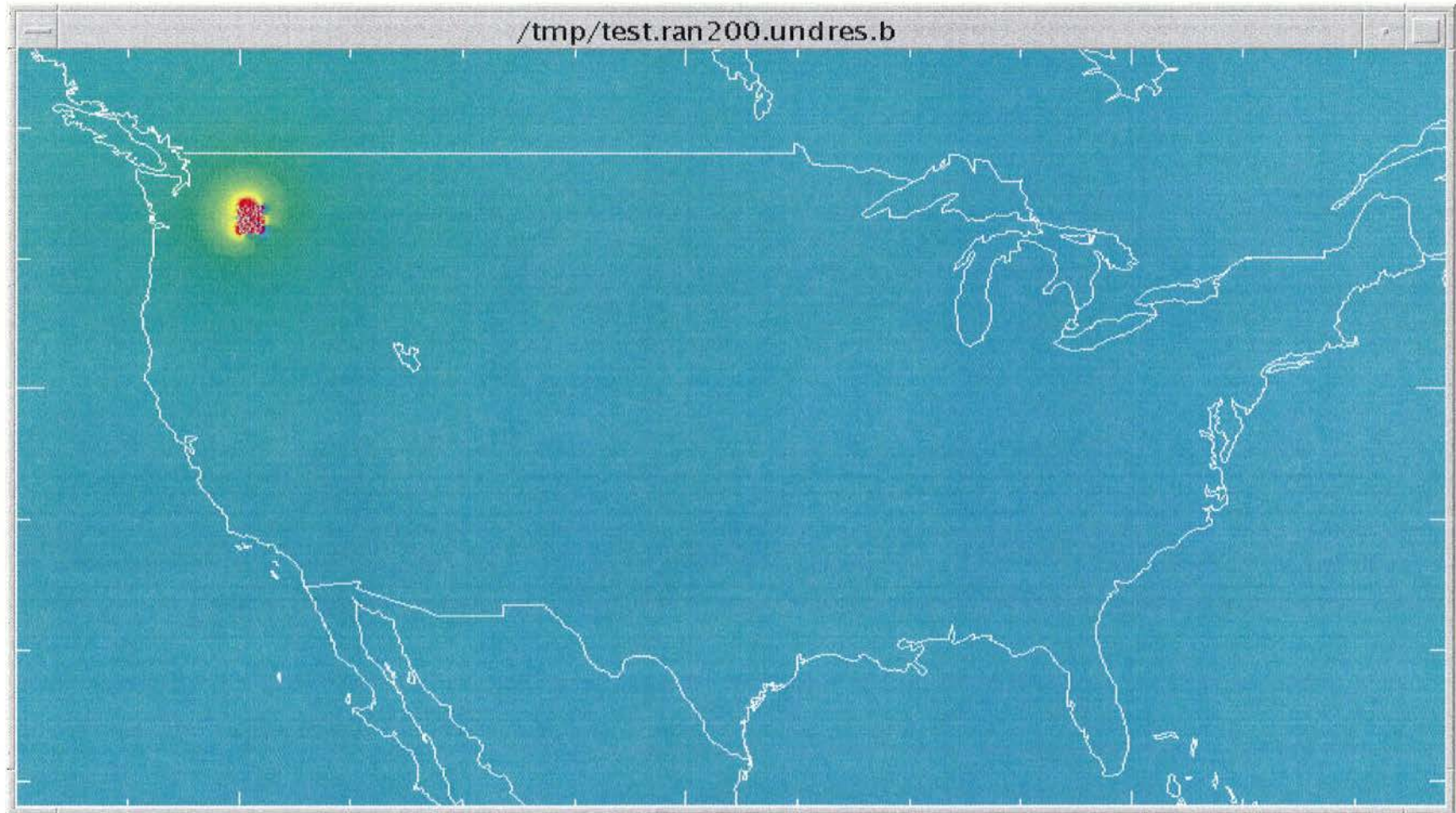
## DMA 1998 DTED minus USGS 3" (44° to 49° N, 237° to 243° E)



**RED = +25 m or greater differences**  
**MAGENTA = -25 m or lower differences**



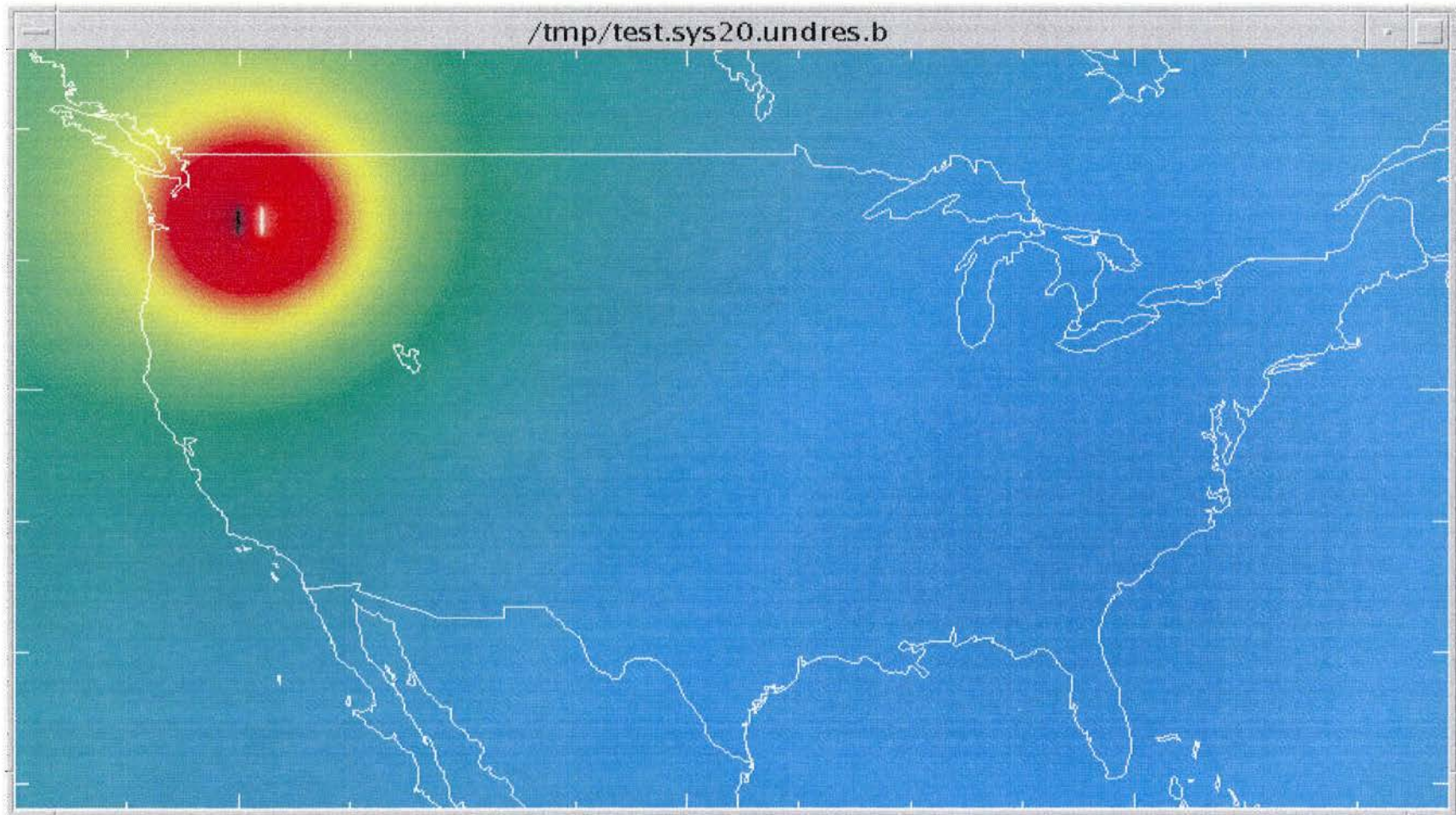
# Geoid Undulation changes due to random $\pm 200$ meter error in one $1^\circ \times 1^\circ$ DEM (of $2' \times 2'$ elevations)



**Red = +1 cm or greater change**  
**Magenta = -1 cm or lower change**



# Geoid Undulation changes due to systematic +20 meter error in one 1°x1° DEM (of 2'x2' elevations)



**Red = +1 cm or greater change**  
**Magenta = -1 cm or lower change**

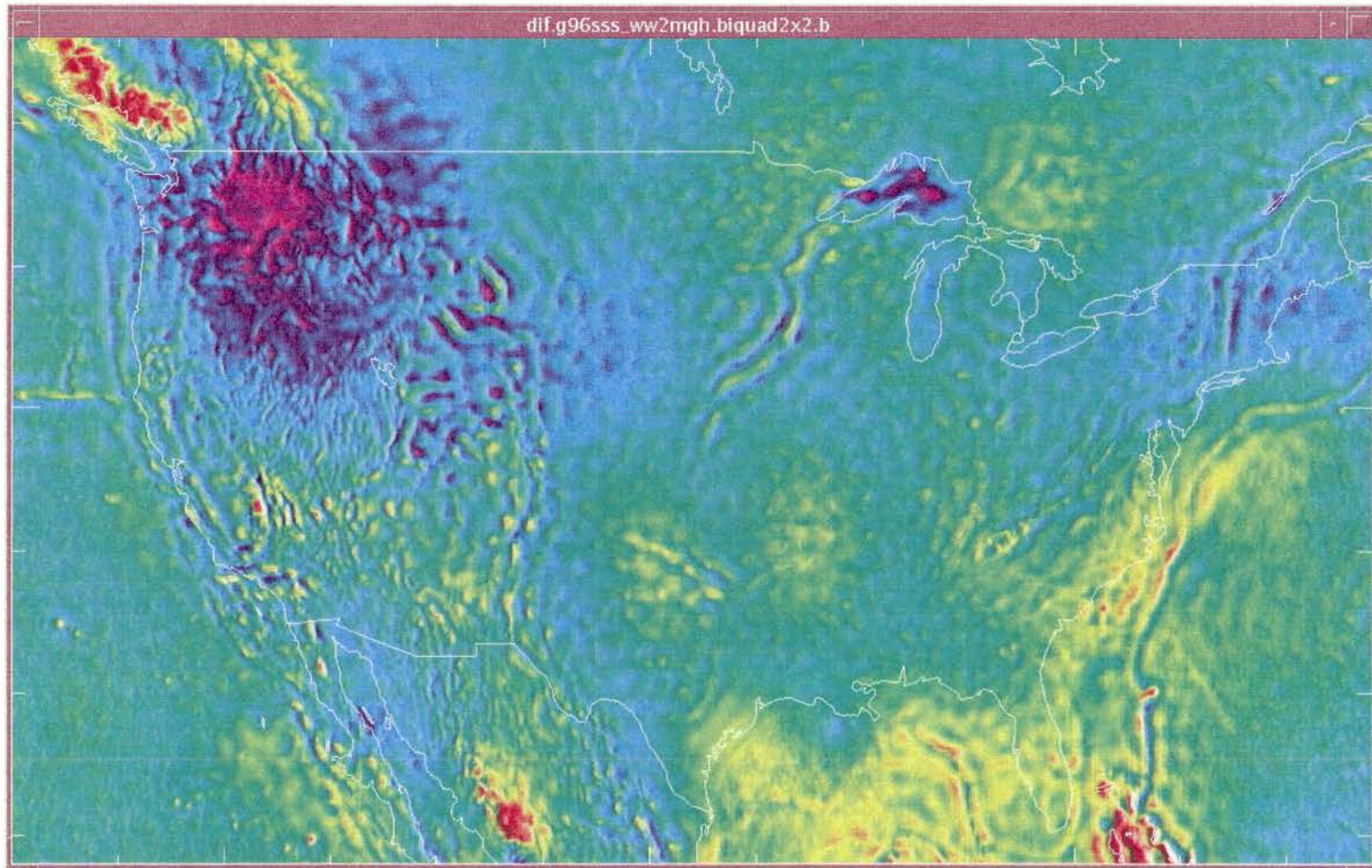
## **Problem #4**

**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

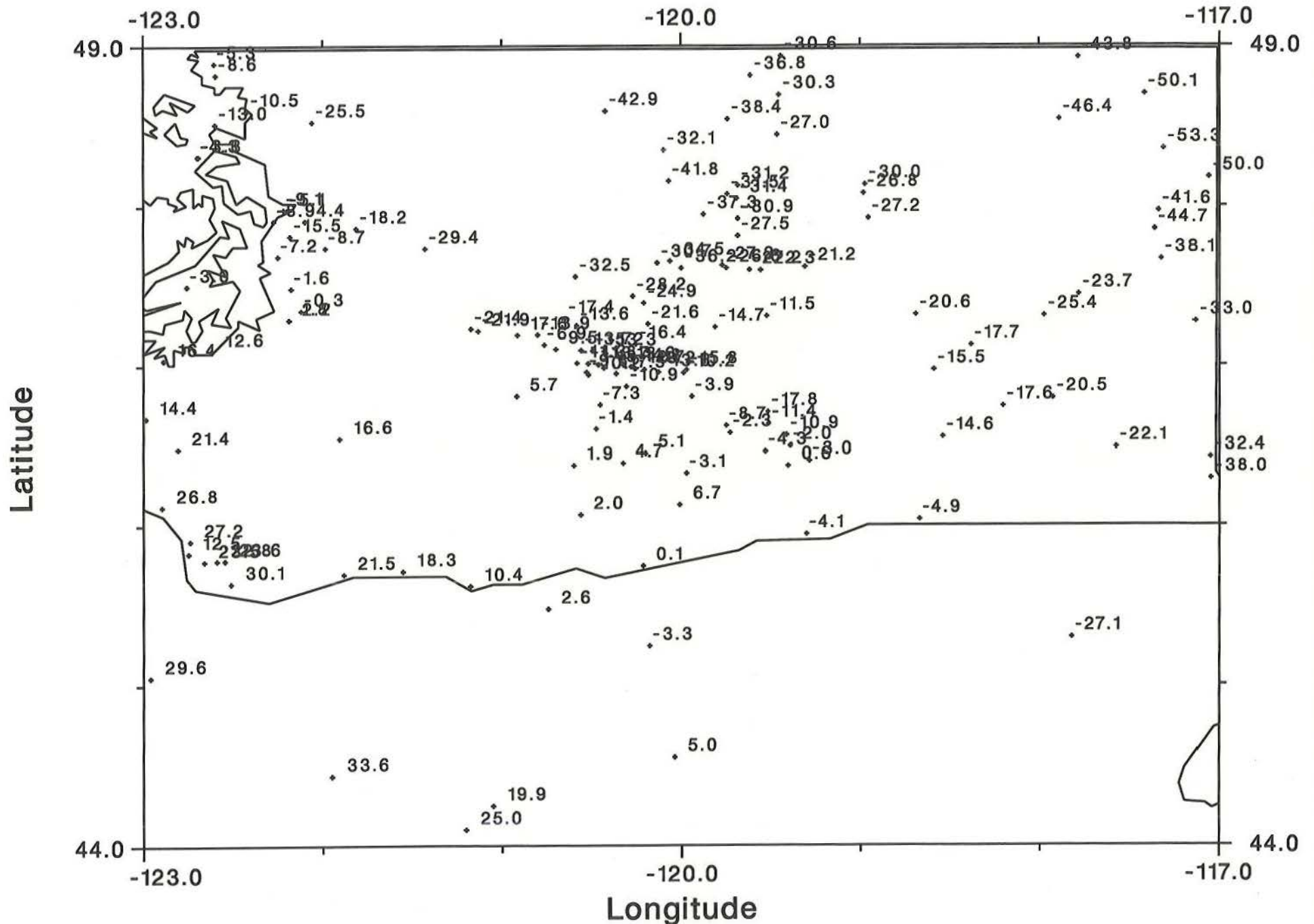
G96SSS/GPS/BM: +43 cm

In PNW (44°-49°, 237°-243°), with average removed:

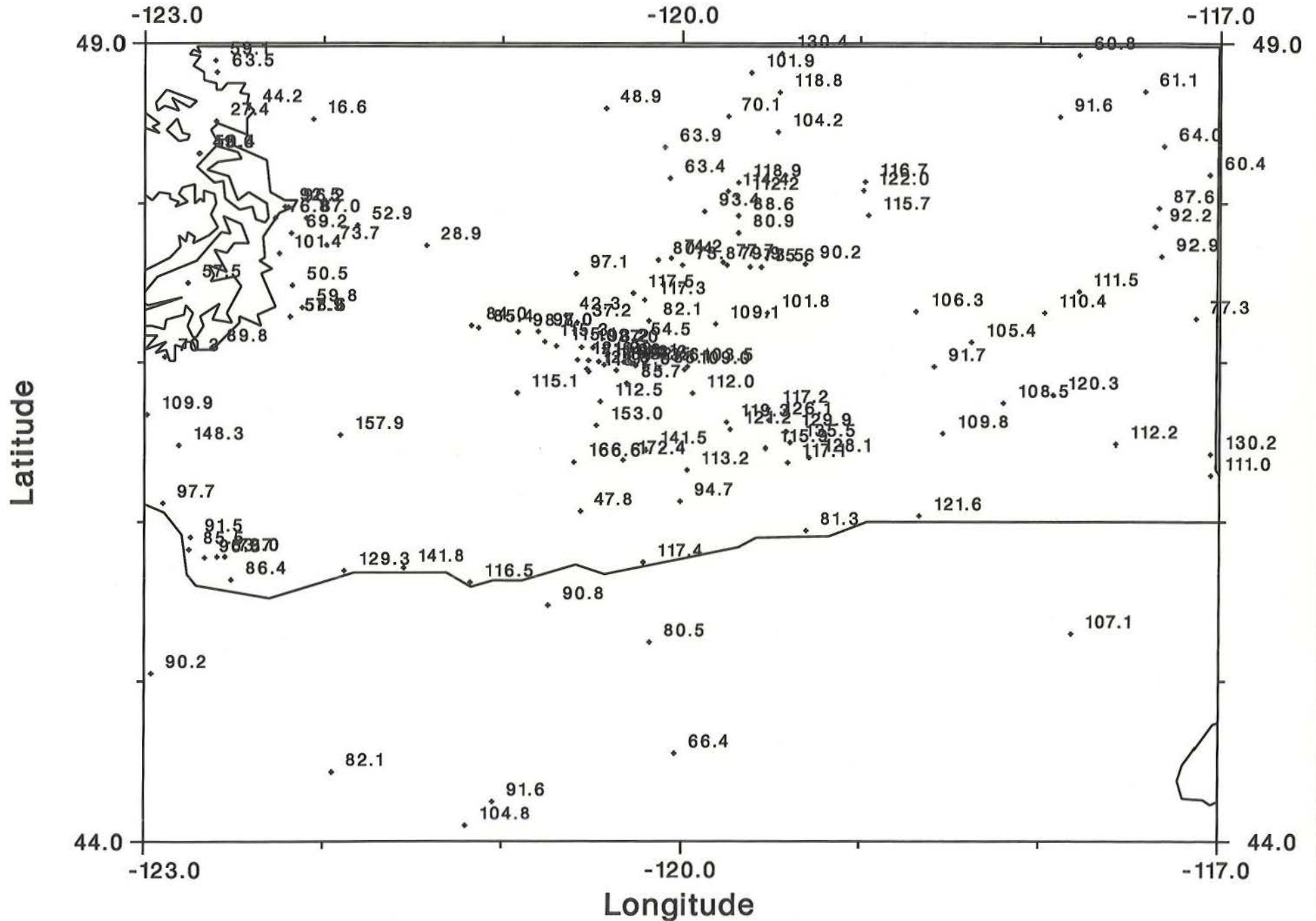
EGM96/GPS/BM: +94 cm ± 28 cm

G96SSS/GPS/BM: -12 cm ± 19 cm

# GPS/BM/G96SSS residuals (about 43 cm ave)



# GPS/BM/EGM96 residuals (about 41 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**