North American Geoid Computations

- **Greenland**
  1996 KMS
- **Canada**
  1995 GSD/GC
- **U.S./Alaska/Hawaii/Puerto Rico**
  1996 NGS
- **Mexico**
  1997 NGS
- **Caribbean Sea**
  1997 NGS/NIMA
- **Central/South America**
  1995 EP-USP

GEOID COMPUTATIONS AT NGS

- 2-D FFT for terrain corrections using 30"x30" DTED
- Downward continuation using normal gravity
- Grid refined Bouguer Anomalies using splines in tension
- Restore Bouguer plate using 2'x2' mean DTED at grid intersections
- Remove geopotential anomalies ($\Delta g_{0\rightarrow360} = -\partial T/\partial r - 2T/r + 2\delta W/r$)
- 1-D FFT w/ mean removal
- Restore geopotential undulations ($N_{0\rightarrow360} = T/\gamma - \delta W/\gamma$)
- Apply 1st order indirect effect using 2'x2' mean DTED at grid intersections

GEOID COMPUTATIONS AT GSD/GC

- Terrain corrections pre-computed using templates, and prism integration
- Remove geopotential anomalies at each point.
  ($\Delta g_{0\rightarrow 360} = -\partial T/\partial r - 2T/r + 2\delta W/r$)
- Downward continuation using normal gravity
- Grid residual refined B.A.'s using collocation to 5'x5' centers of cells.
- Restore Bouguer plate using 5'x5' mean DTED at centers of cells
- 2-D FFT w/ mean removal, 6 band
- Restore geopotential undulations
  ($N_{0\rightarrow 360} = T/\gamma - \delta W/\gamma$)
- Apply 1st order indirect effect using 5'x5' mean DTED at grid intersections

GEOID COMPUTATIONS AT KMS

- 1 km x 1 km DTED
- Compute and remove gravity RTM signal about mean DTED (100 km resolution)
  (approx. through $2\pi G\rho(h-h_r)$-TC)
- Remove geopotential surface gravity anomalies ($\Delta g^s_{0\rightarrow 360} = -\partial T/\partial r - 2T/r$)
- Collocation or FFT to produce gridded residual (quasi-)geoid undulations
- Restore geopotential surface height anomalies ($N_{0\rightarrow 360} = T/\gamma$)
- Compute and apply geoid RTM effect to yield (quasi-)geoid undulations

MOLODENSKII METHOD (G9501)

- 30"x30" DTED, Center of Cell
- 2-D FFT for classical terrain corrections
- Grid refined Bouguer Anomalies using splines in tension
- Restore Bouguer plate using 3'x3' mean DTED at grid intersections
- Assume $\Delta g_{TF} = \Delta g_{surf} + G_1$
- Remove geopotential surface gravity anomalies ($\Delta g^{s}_{0\rightarrow 360} = -\partial T/\partial r - 2T/r$)
- 2-D FFT , $S(\Delta g_{TF}) = S(\Delta g_{surf} + G_1)$
- Restore geopotential surface height anomalies ($\zeta_{0\rightarrow 360} = T/\gamma - \delta W/\gamma$)
- Apply height anomaly to geoid undulation correction, using simple Bouguer anomalies and 3'x3' mean DTED

THEORETICAL ISSUES

- Attempt to write theory at 1 cm level to anticipate future data support.
- Density anomaly data?
- RTM vs. "classical" terrain reductions?
- Spherical Terrain reductions?
- Downward continuation in Helmert Space? Using H? Using g? Using γ?
- Gridded vs. pt. gravity values?
- Spectral content of geoid signal to 1 cm (i.e. omission error < 1 cm at 5'? 2'?)
- Ellipsoidal Stokes' Kernel?
- Analytical compatibility of gravity reductions and indirect effect?

MARGIN OF VARIATION

- NGS and GSD/GC have used the same theory.
- Molodenskii method is very similar, under defining assumptions
- KMS uses a modified version of Molodenskii

- Many large (> 10 cm) NGS geoid issues have been data related
- G96SSS vs GSD95 disagreements seem data related (theory is the same).
- G96SSS vs MEXICO97 vs CARIB97 disagreements are data related

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

	TOPO30	1995 Canadian DTED
Ave	12 mgals	14 mgals
RMS	17 mgals	19 mgals
Min	-17 mgals	-12 mgals
Max	+45 mgals	+54 mgals

- 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

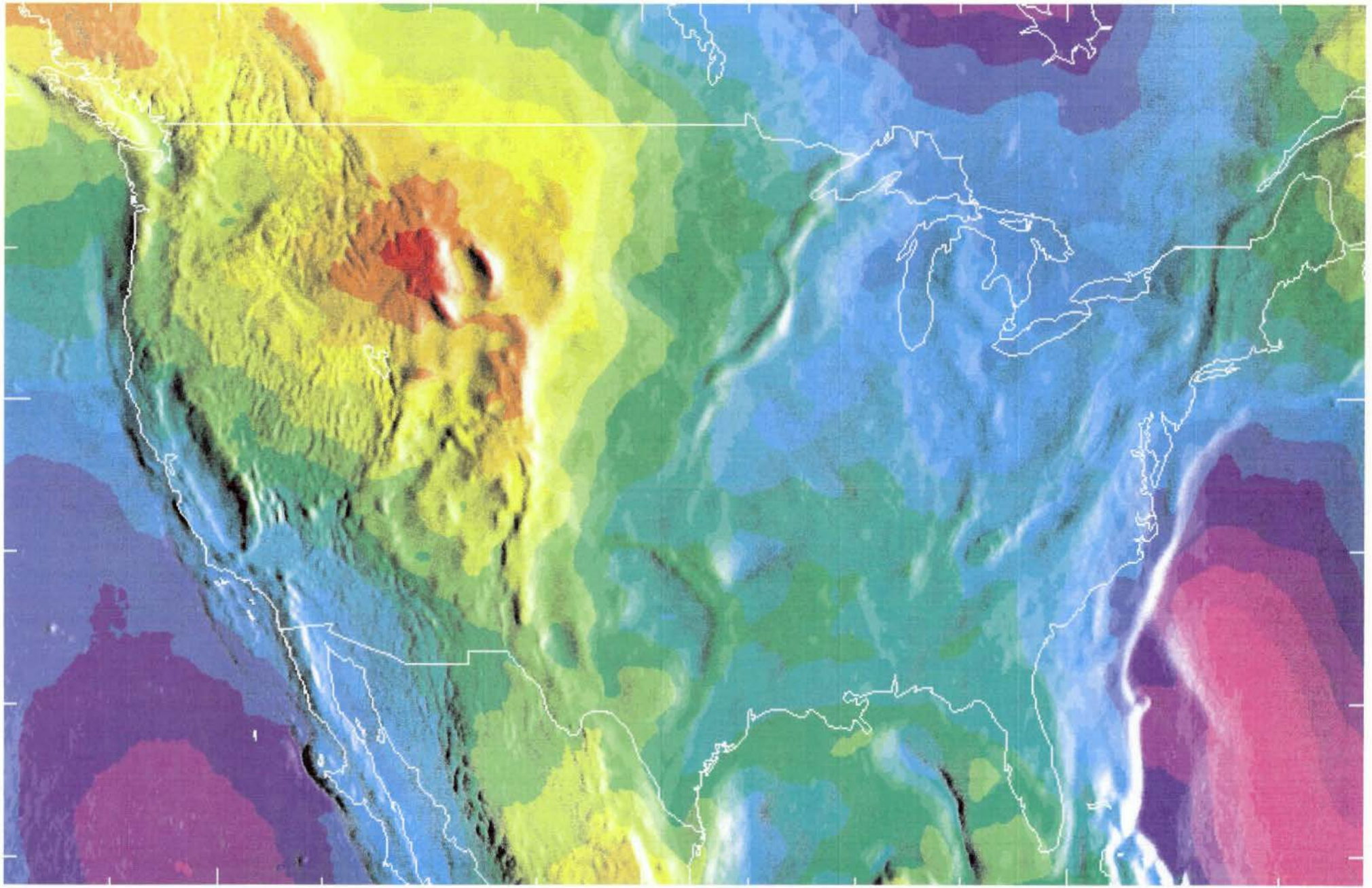
CANADIAN TERRAIN CORRECTIONS (Jan 93)
Preliminary Results

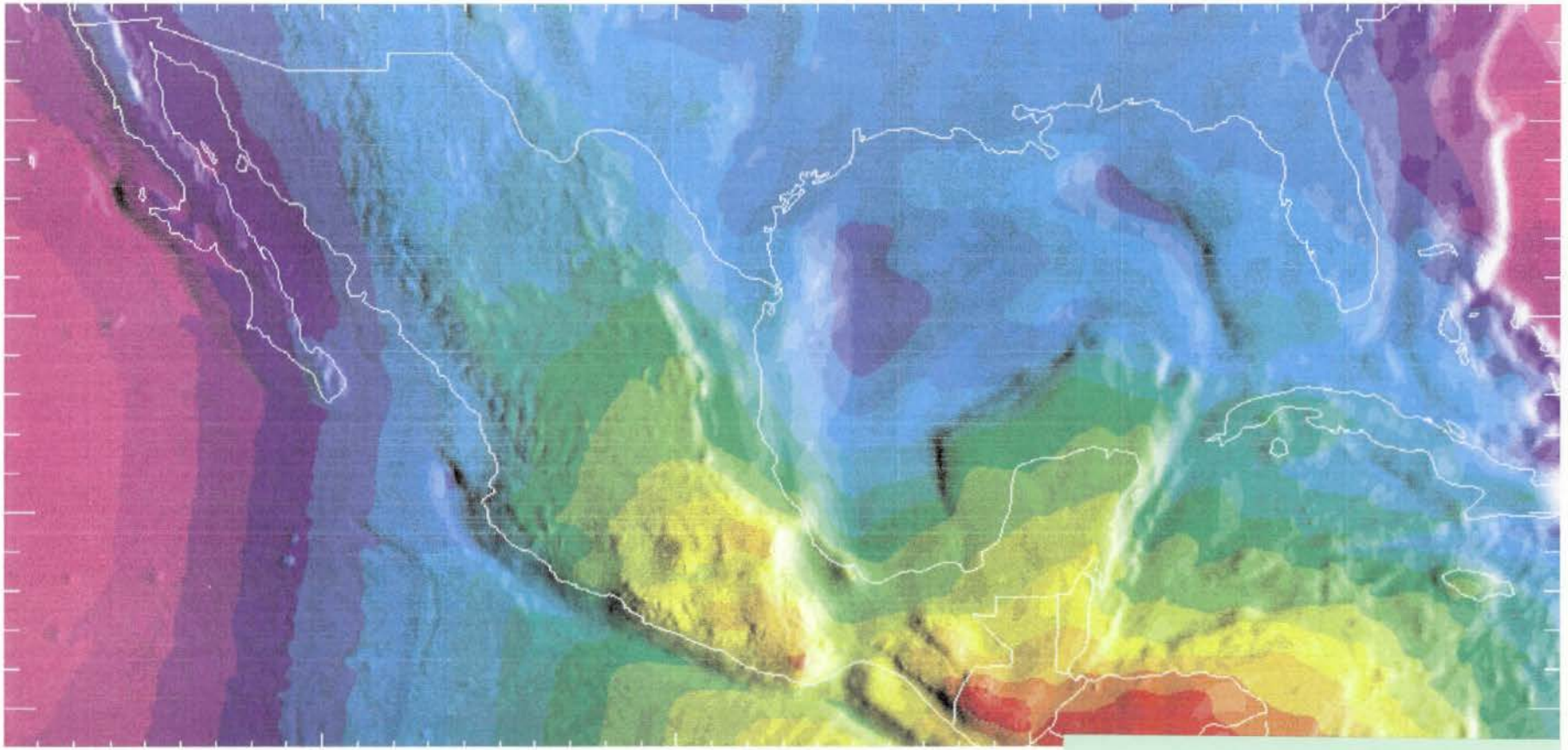
- Unable to reproduce the January 1993 TC's

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

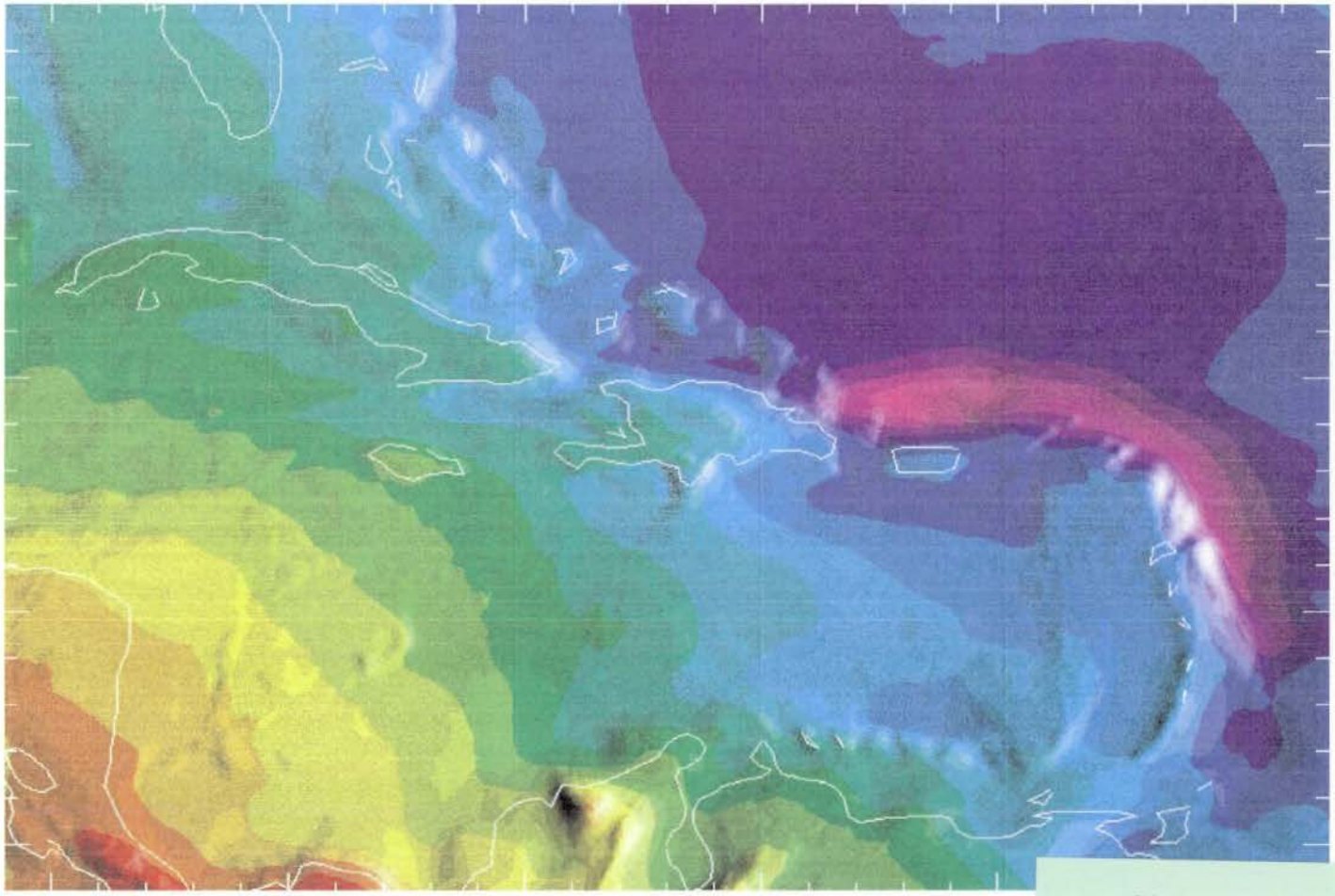
- FFT method agrees to within +/- 1 mgal with prism methods, except for large (>30 mgal) spikes, where the FFT is systematically too low by an average of 8 mgals

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

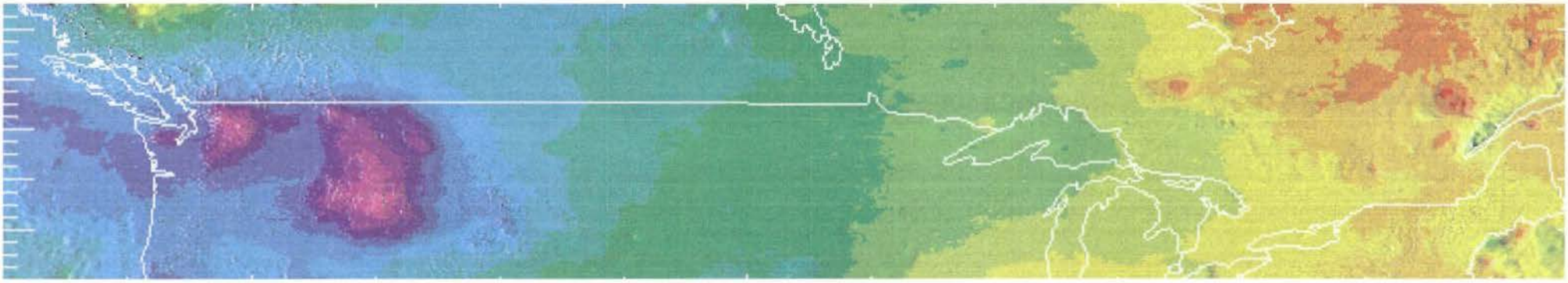




−47.6 to 6.8



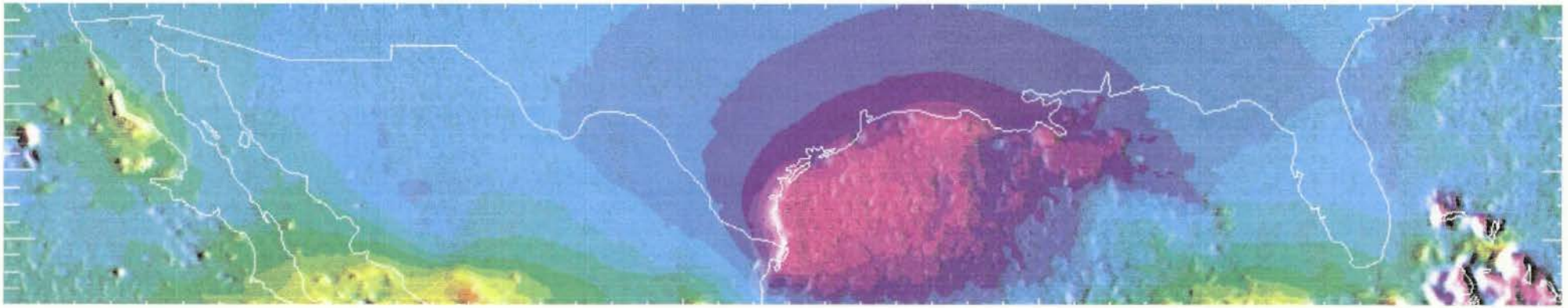
−71 to 17



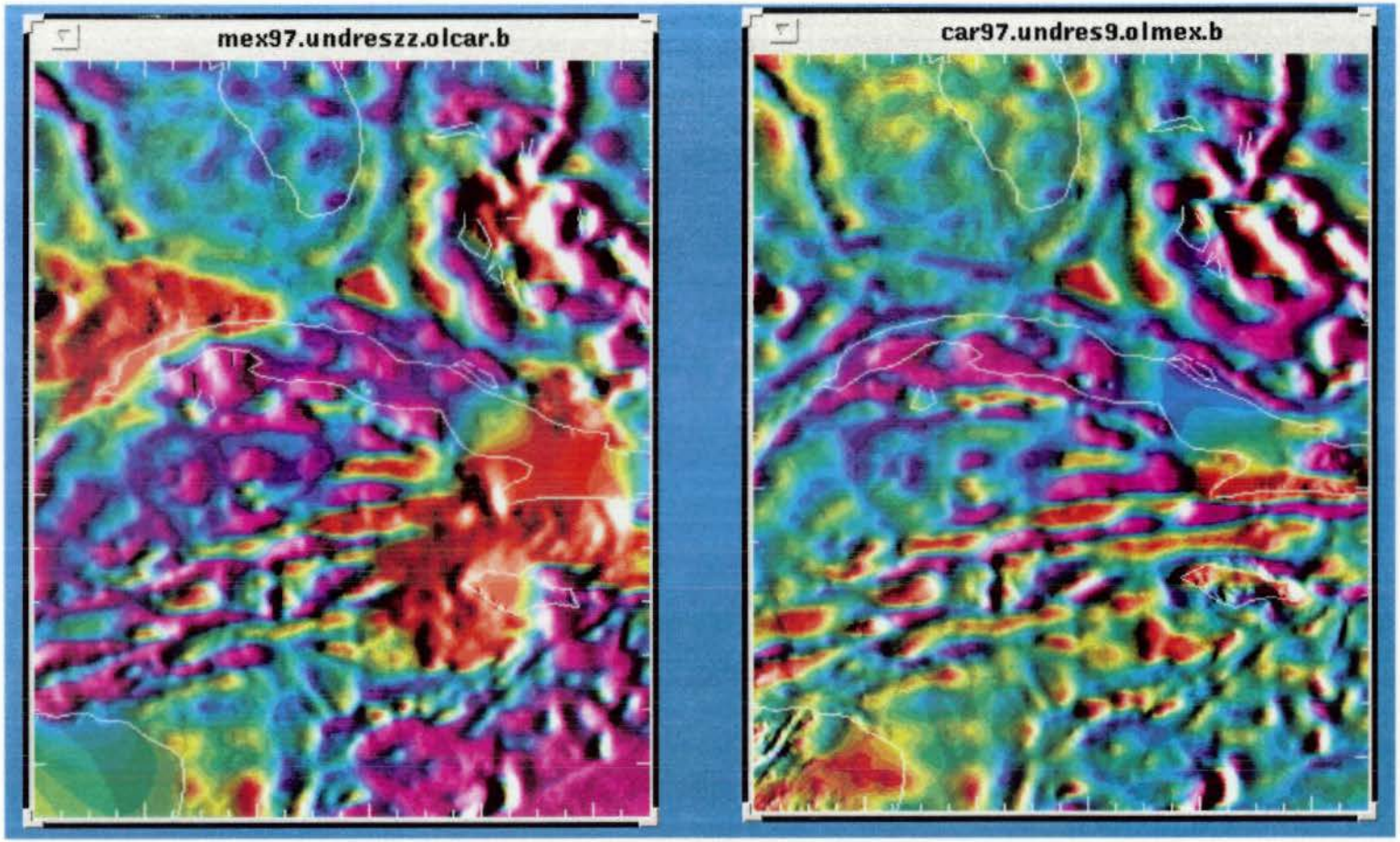
P7: -2.16 m

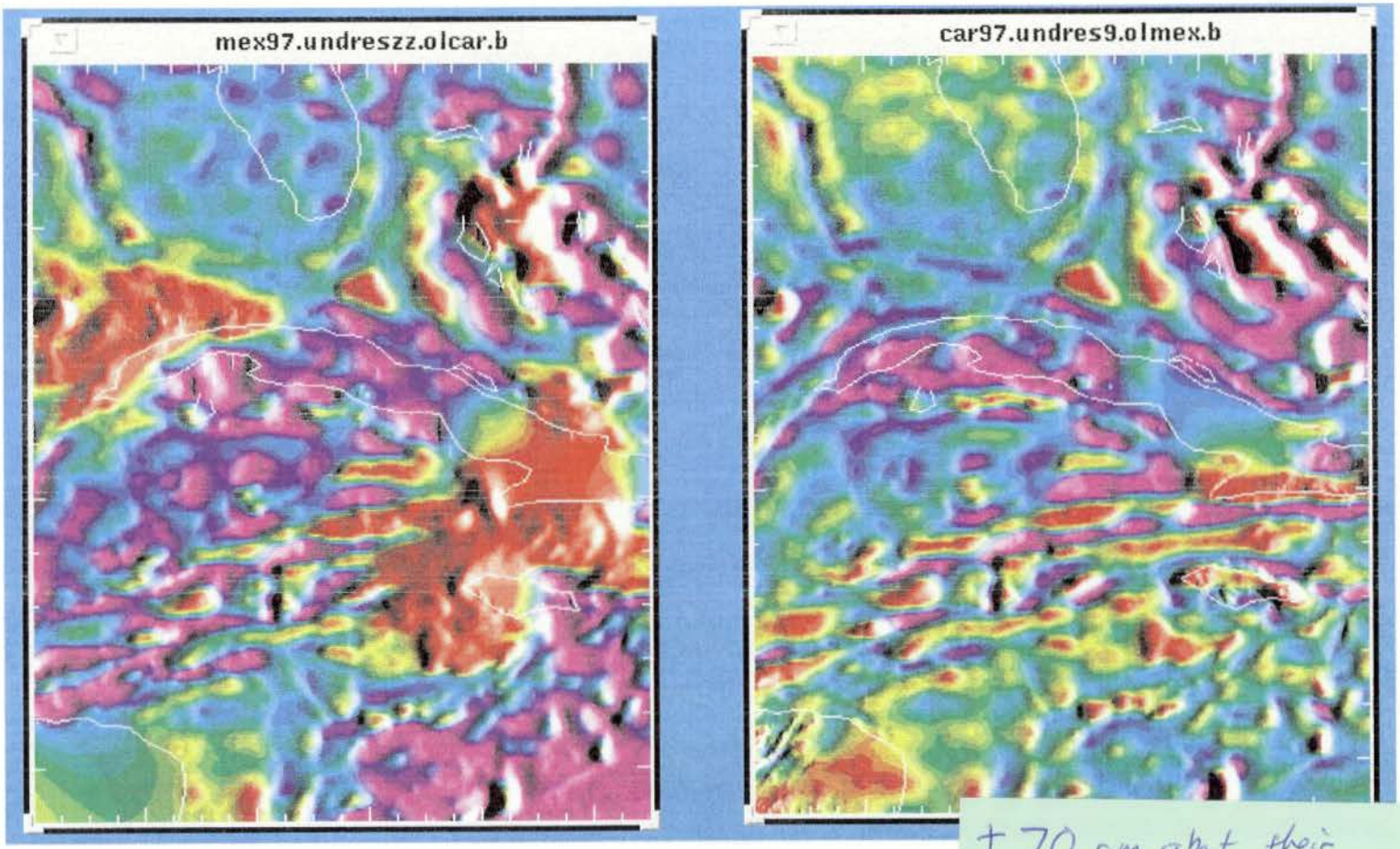
Tilt ≈ 1.25 m E/W

= 0.28 ppm



-2.2 m in Bight
-1.5 m in Gulf
80 cm Tx / ea tilt
Mexno edge peak is due to
diffkt TC's & Texas


mex97.undreszz.olcar.b
car97.undres9.olmex.b

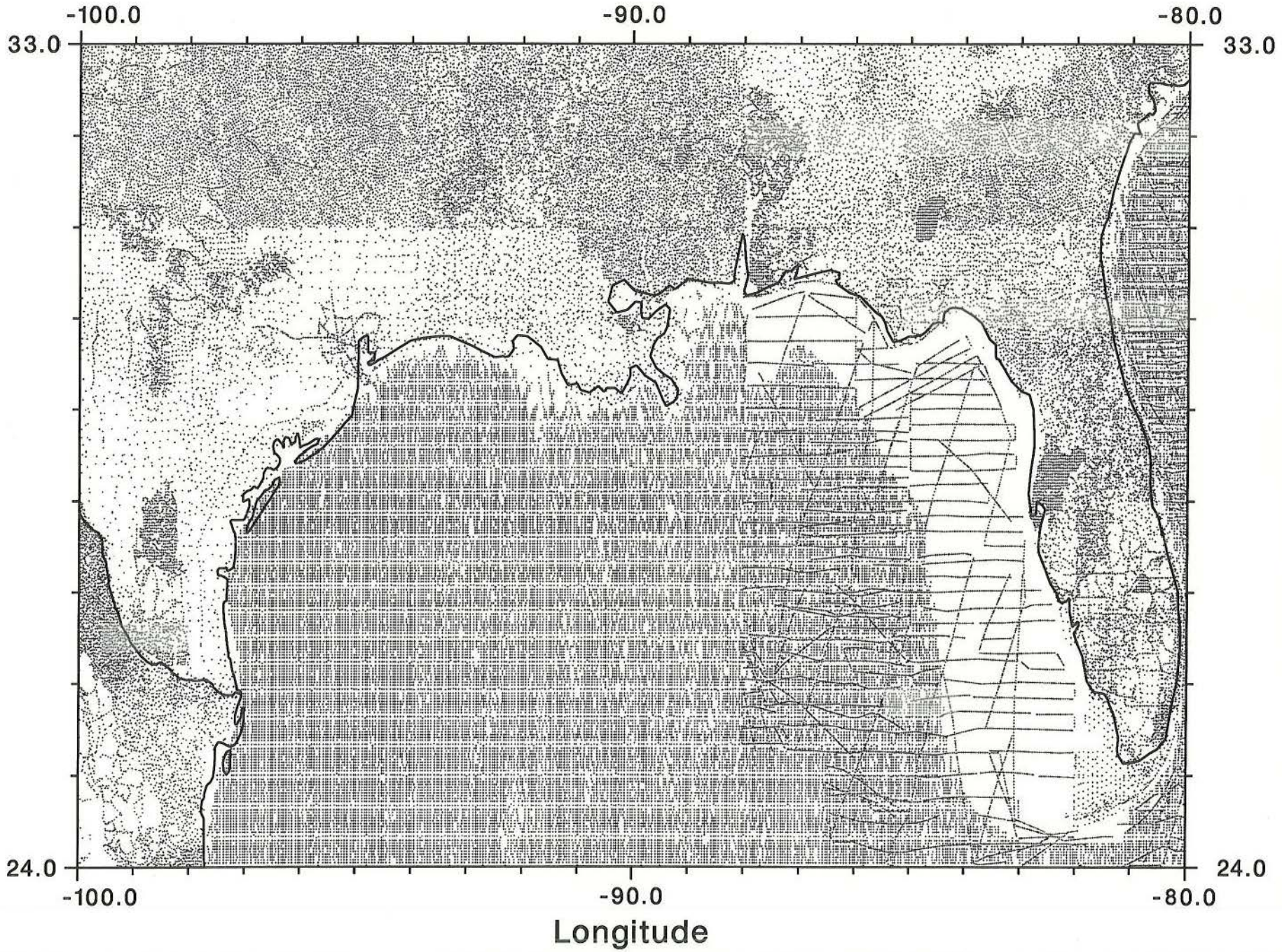


± 70 cm about their averages:

Left/Mex/ (S/S) $\bar{x}$ = 36 cm / σ = 67 cm / -1.6 to +3.5 m

Rt/Car/ (KMS) $\bar{x}$ = -26 cm / σ = 38 cm / -1.8 to +2.0

Thinned Bouguer Anomaly Pts (MEXICO97)



Thinned Bouguer Anomalies (GEOID96)