NAVD 88 Helmert Orthometric Heights from NAD 83 GPS heights and the GEOID99 high resolution geoid height model
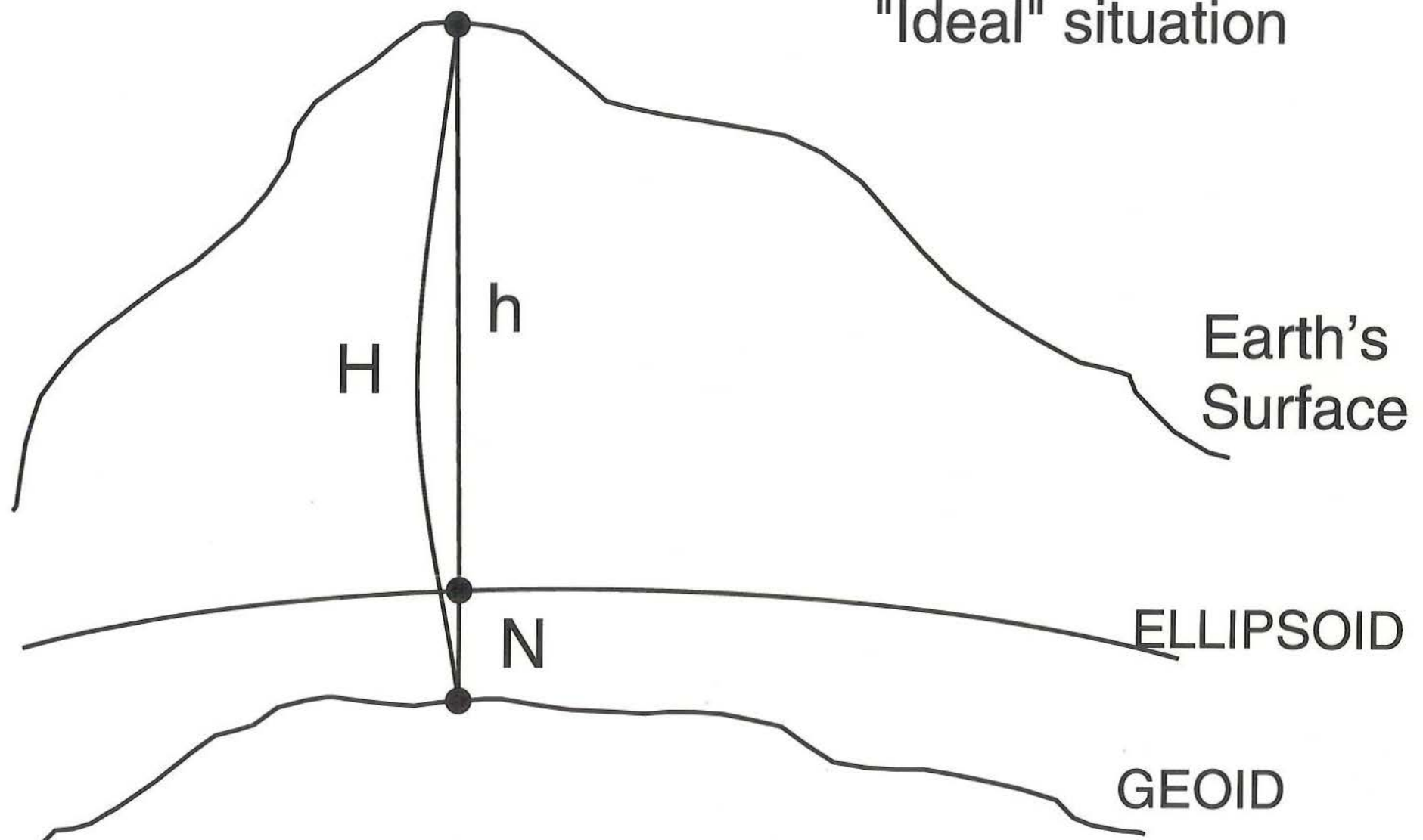
Dru A. Smith, Ph.D.
Daniel R. Roman, Ph.D.
National Geodetic Survey
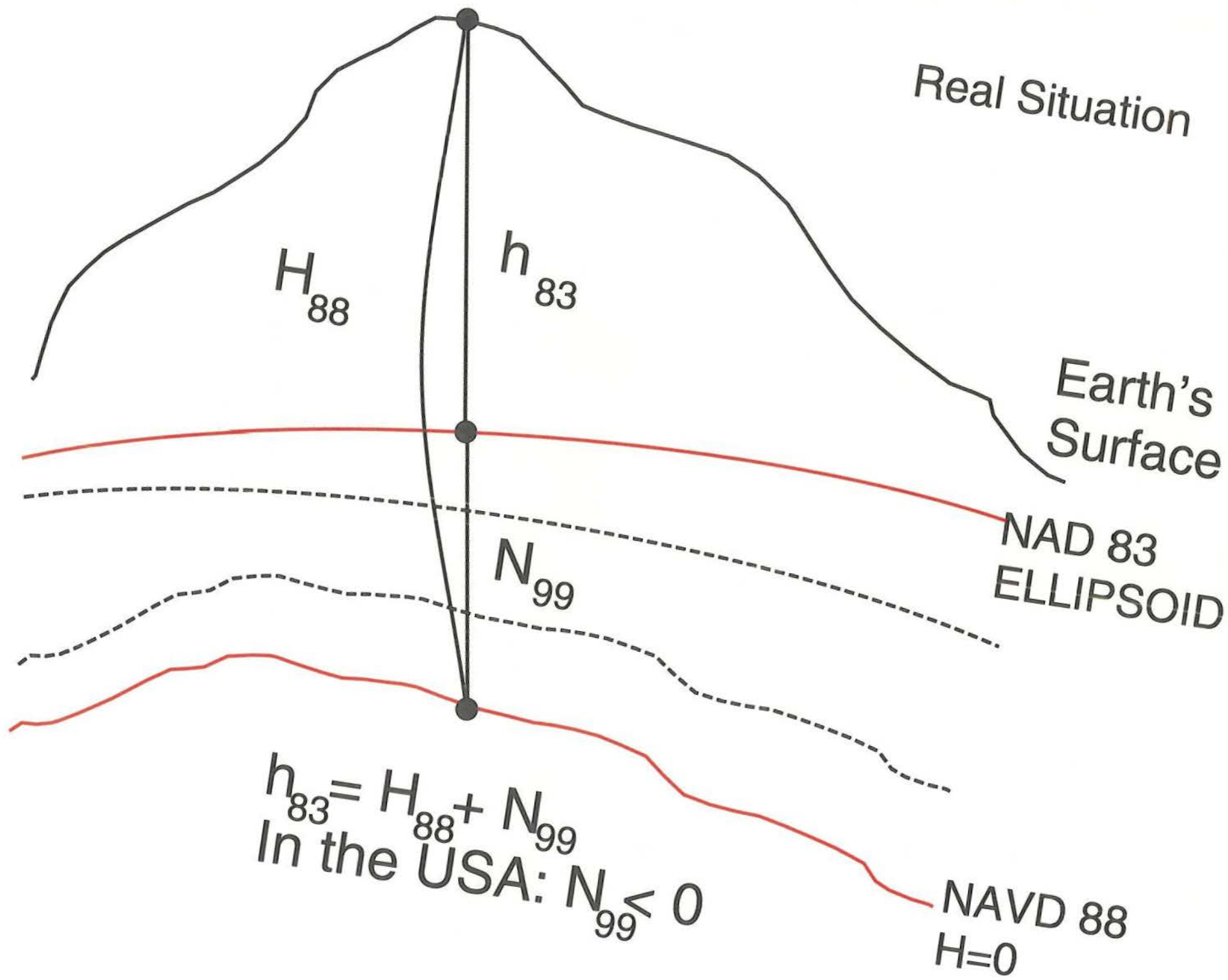
- Review of Height Systems

- Status of HARNS

- Creation of GEOID99 model

- Comparison with GEOID96

- Accuracy analysis of "GPS leveling"

"Ideal" situation

Earth's Surface

ELLIPSOID

GEOID

$$h = H + N$$
In the USA: $N < 0$

Real Situation

H_{88} h_{83}

Earth's
Surface

NAD 83
ELLIPSOID

N_{99}

$h_{83} = H_{88} + N_{99}$
In the USA: $N_{99} < 0$

NAVD 88
$H = 0$

STATUS of the HARNs

- 1998 :   Last of original 48 CONUS HARNs
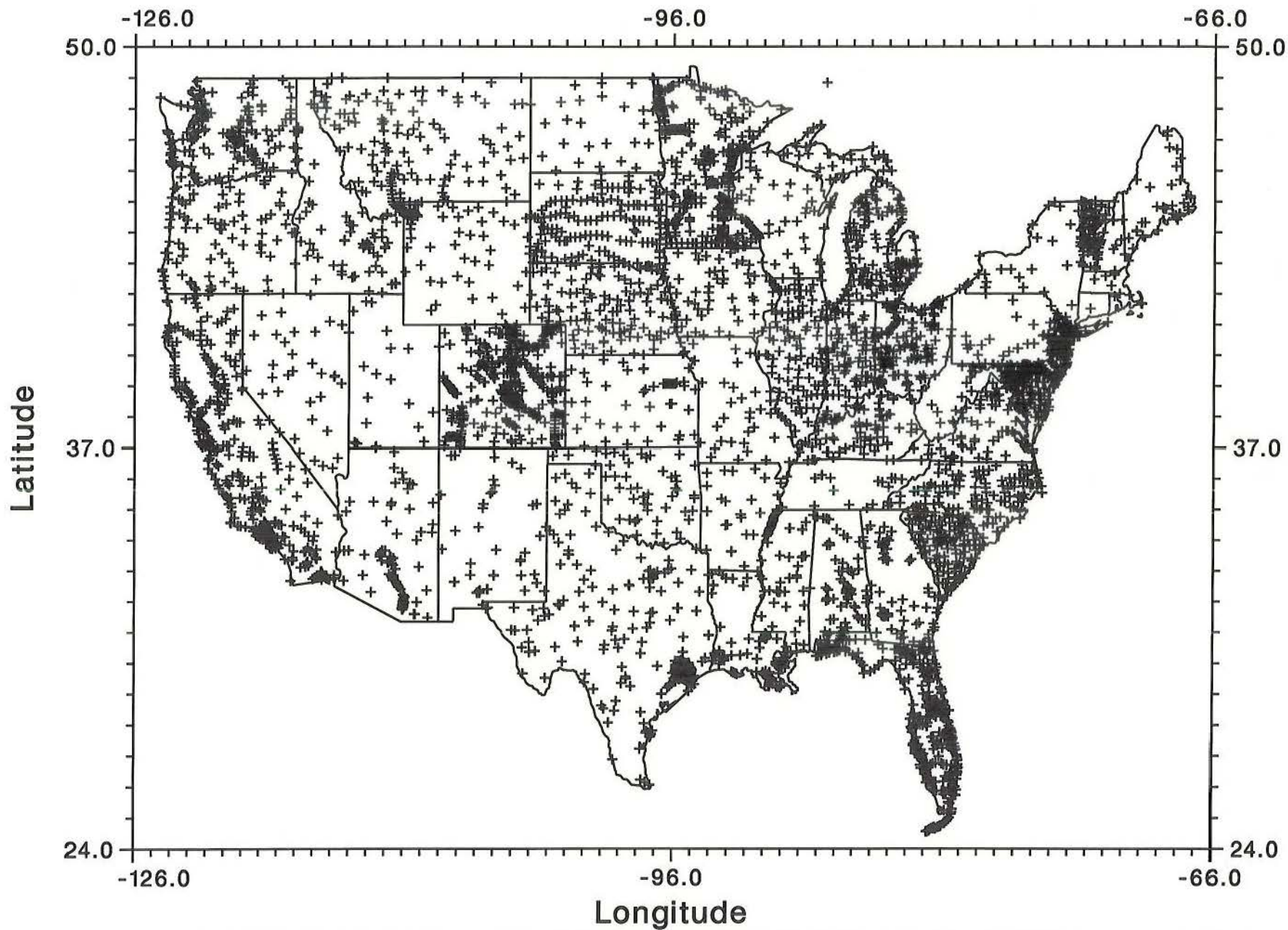
    NGS begins FBNVC (FBN Vertical Component)

- 1999 :   Wisconsin FBNVC observed, processed, loaded
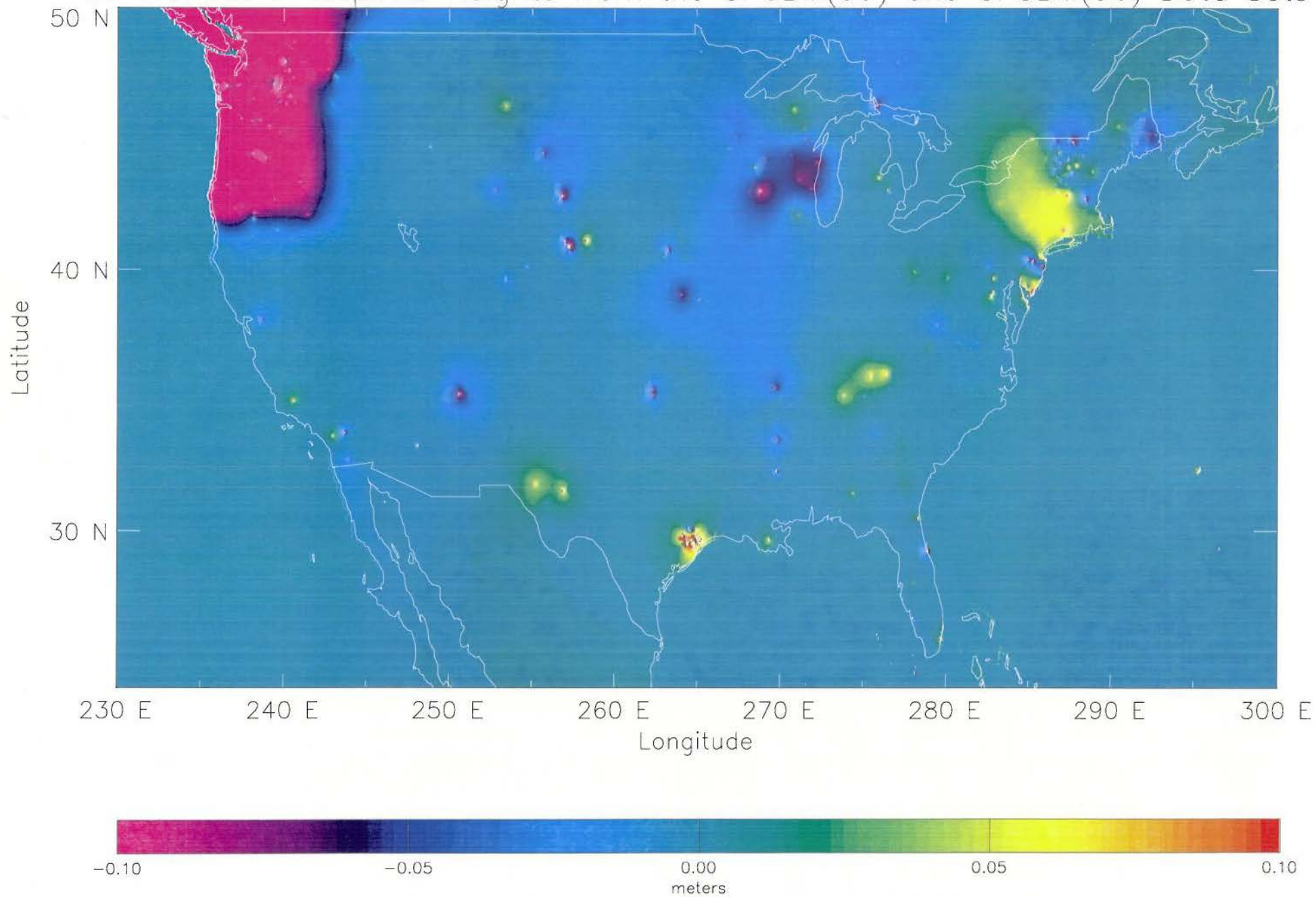   into NGSIDB

    Washington and Oregon FBNVC observed and
    preliminarily processed. Not loaded into NGSIDB.

    GEOID99 released, reflecting 45 original HARNs
    and 3 FBNVC states (WI, WA, OR)

GPS/BMs for GEOID99 (6169 points)

Differences in Ellipsoid Heights from the GPSBM(99) and GPSBM(96) Data Sets

GEOID99 basic information

Input data
- 2.0 Million gravity observations (1.6 from the NIMA evaluated gravity database)
- 0.6 Million altimetric gravity anomalies
- EGM96 (NASA/NIMA)
- 1 km DEM supplemented by 30 m DEM in Northwest USA
- 6169 GPS heights on leveled benchmarks

Theory
- Faye anomalies $\cong$ Helmert anomalies
- Remove/Compute/Restore using EGM96 and 1-D FFT
- Collocation to model h-H-N long wavelength systematic differences

Output Grids
- 1 arc-minute grids
- CONUS: up to 58 degrees North
- Alaska, Hawaii, Puerto Rico/Virgin Islands

30 meter DEM in Northwest USA

- USGS makes 30 meter DEMs available in 7.5 minute quadrangular areas on UTM grid

- NGS acquired, cleaned, and regridded the data onto 1 arcsecond grid in the region 39/49 North and 231/256 East (NGSDEM99)

- Decimated 3 arcsecond DEM used for terrain corrections

- Geoid impact of new DEM in Northwest USA:
    ~14 cm (1 σ) locally (max +/- 40 cm)
    ~7 ppm tilts (1 σ) (max +/- 200 ppm)
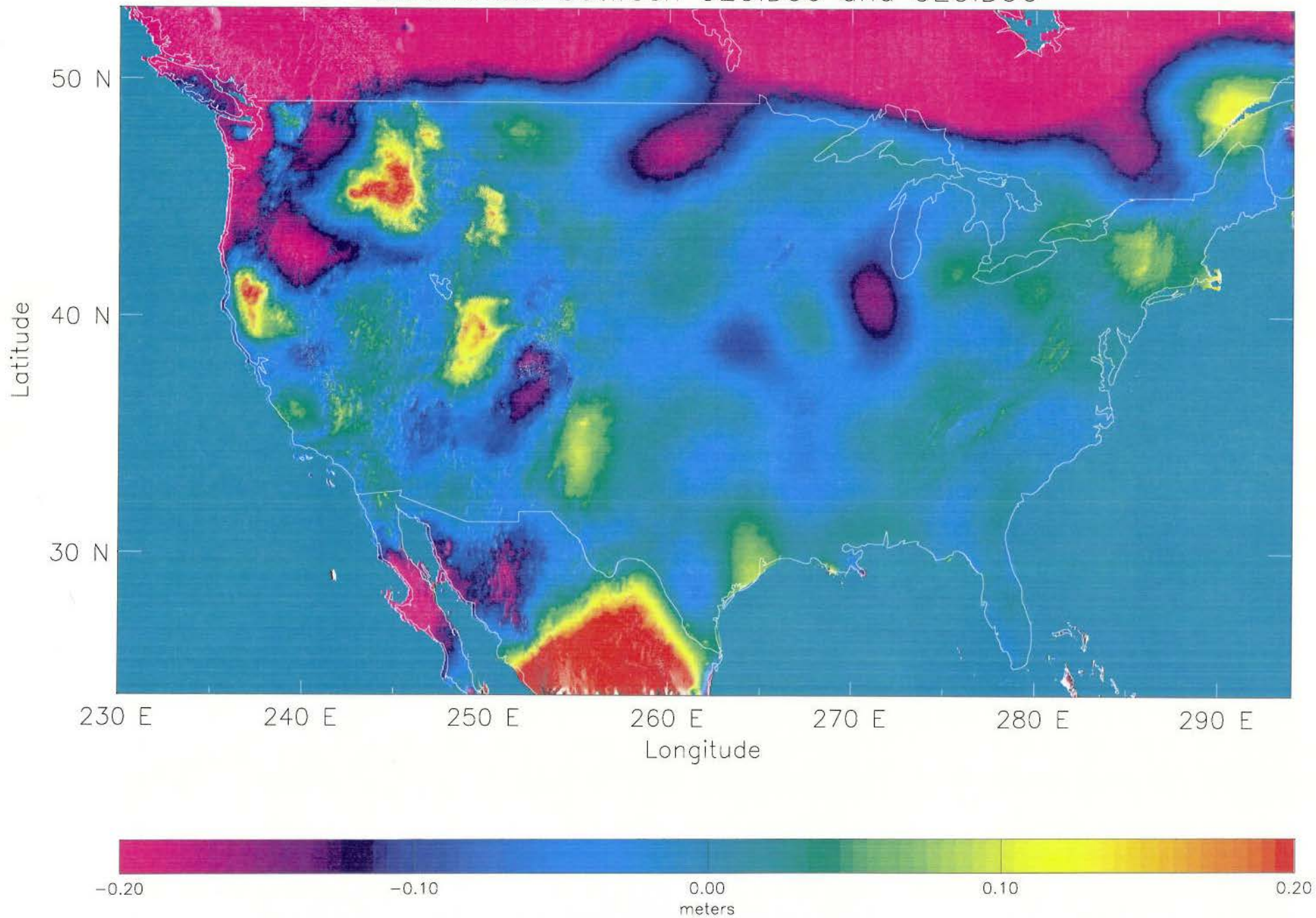
dem_n39_15x15.b
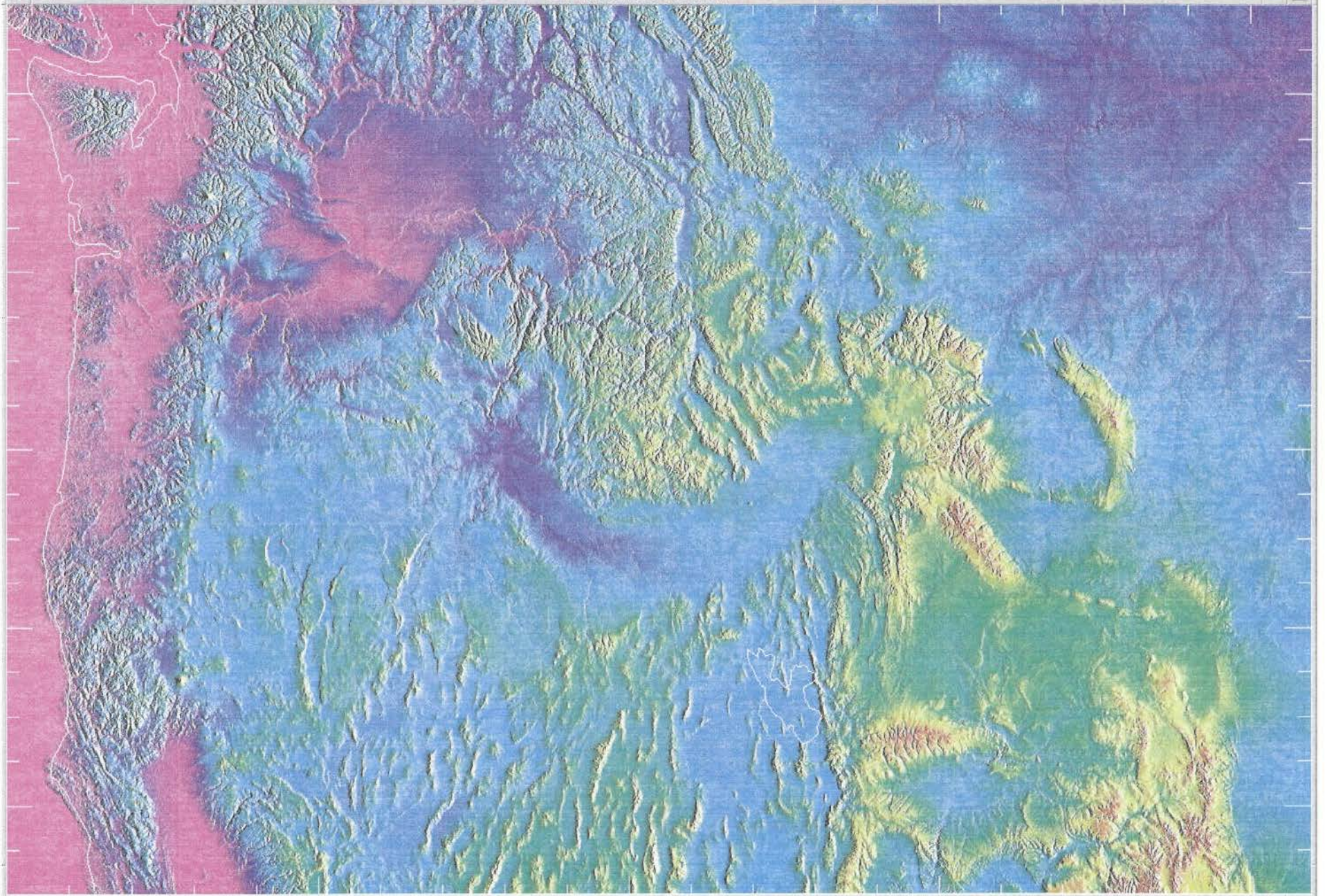
GEOID99
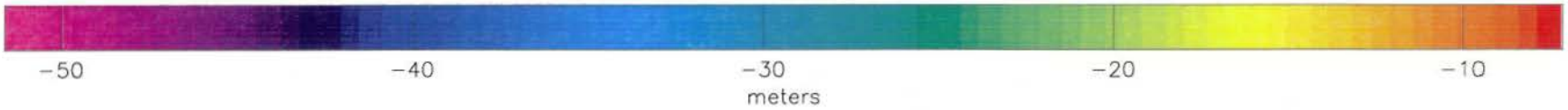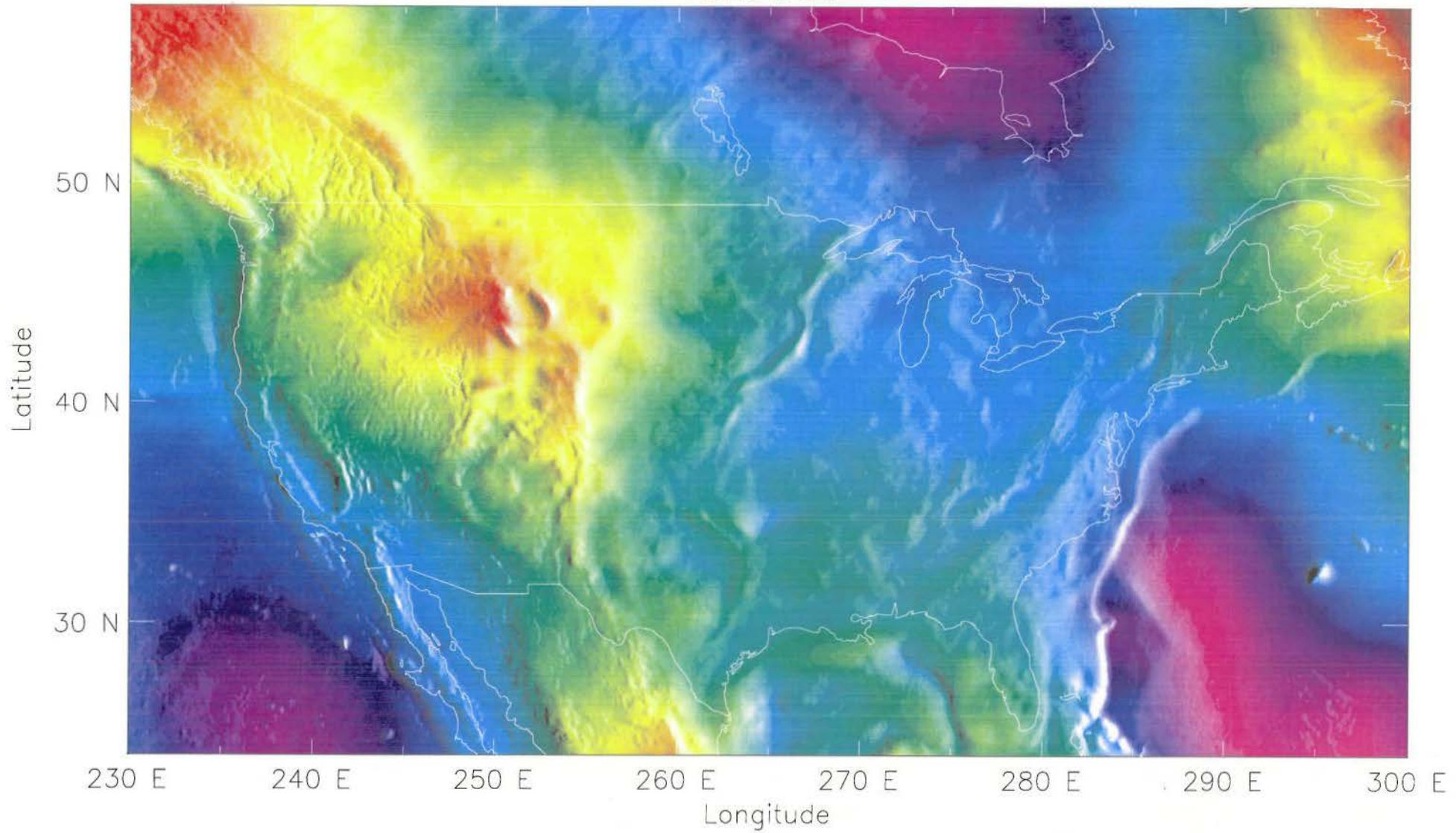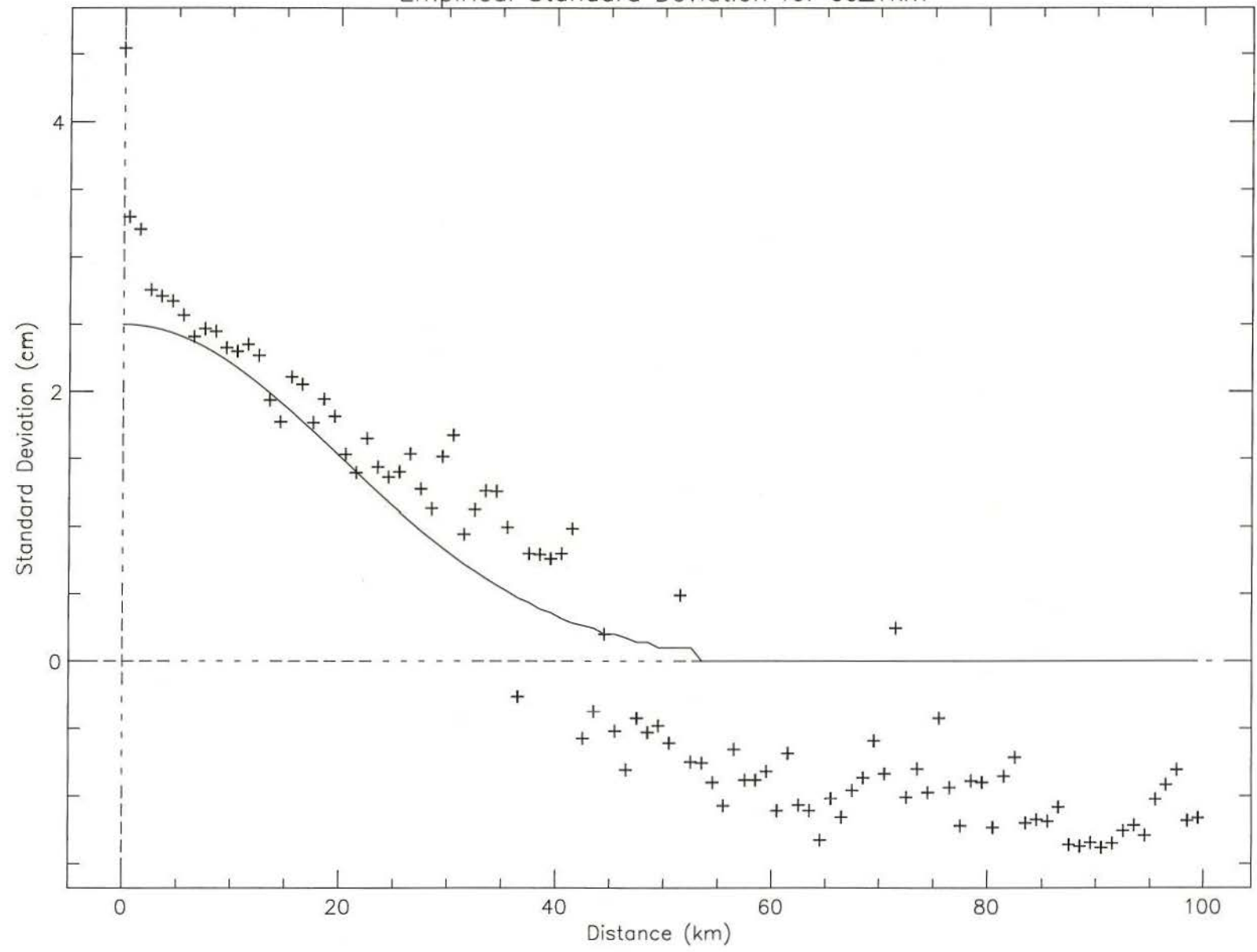
Differences between GEOID99 and GEOID96

GEOID96 vs GEOID99

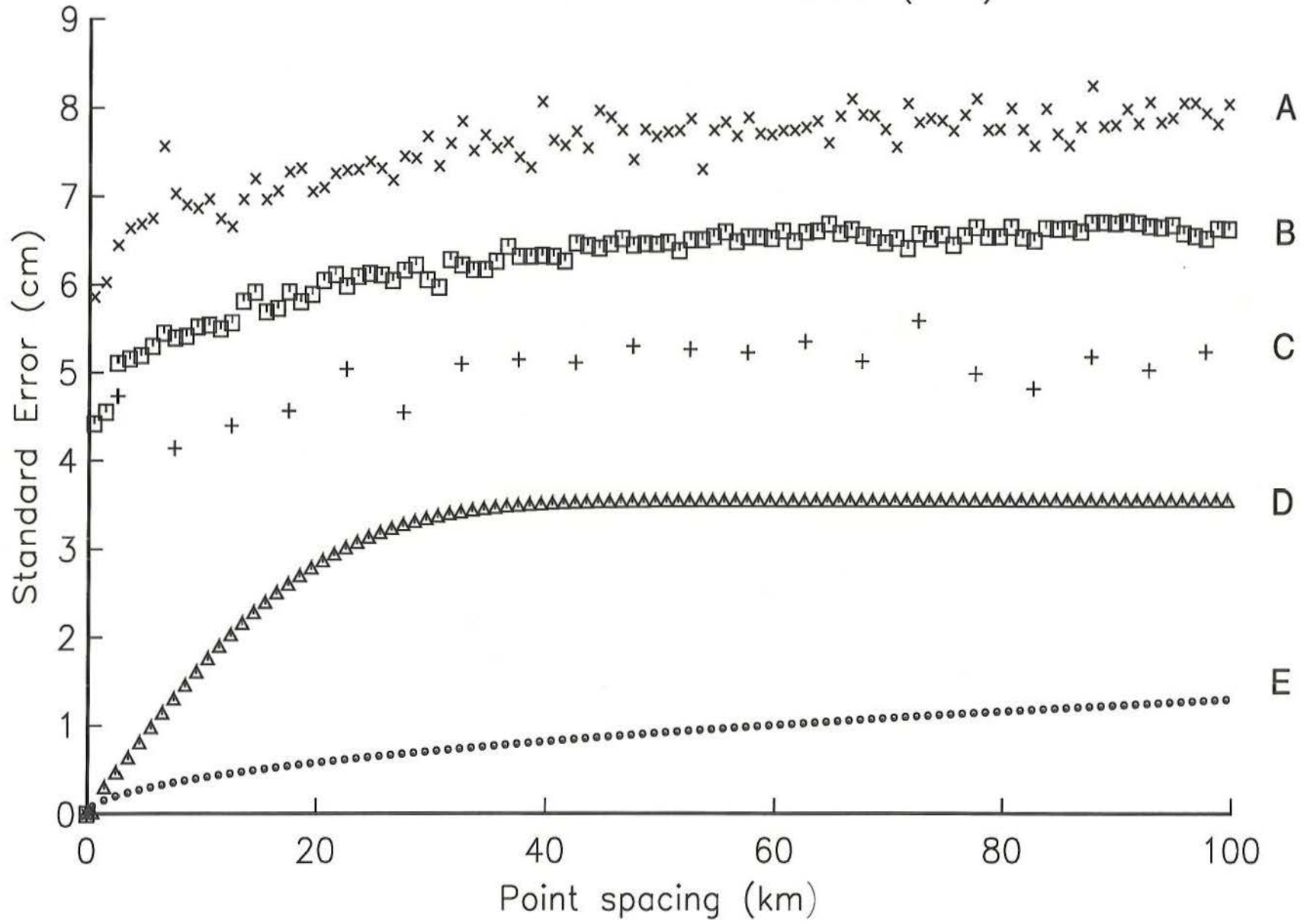|	GEOID96	GEOID99
Grid	2'x2'	1'x1'
North edge	54	58
DEM	TOPO30 (30")	corrected TOPO30 and 1" NGSDEM99
TCs	30"	3" and 30"
GPS/BMs	2951	6169
NAVD 88 bias	-31 cm	-52 cm
RMS wrt GPS/BMs	5.5 cm	4.6 cm

Empirical Standard Deviation for ee_1km

Standard Deviation of differential (h−N)

DIFFERENTIAL (SINGLE TIE) GPS-DERIVED ORTHOMETRIC HEIGHT ACCURACY

LINE	Description	5 km lines σ (ppm)	10 km lines σ (ppm)
A	GEOID96	6.7 cm (13 ppm)	6.9 cm (6.9 ppm)
B	GEOID99	5.2 cm (10 ppm)	5.5 cm (5.5 ppm)
C	GEOID99* (WA,OR,WI)	4.7 cm (9.4 ppm)	4.1 cm (4.1 ppm)
D	GEOID Error only?	0.8 cm (1.6 ppm)	1.6 cm (1.6 ppm)
E	2nd order, class II	0.3 cm (0.6 ppm)	0.4 cm (0.4 ppm)

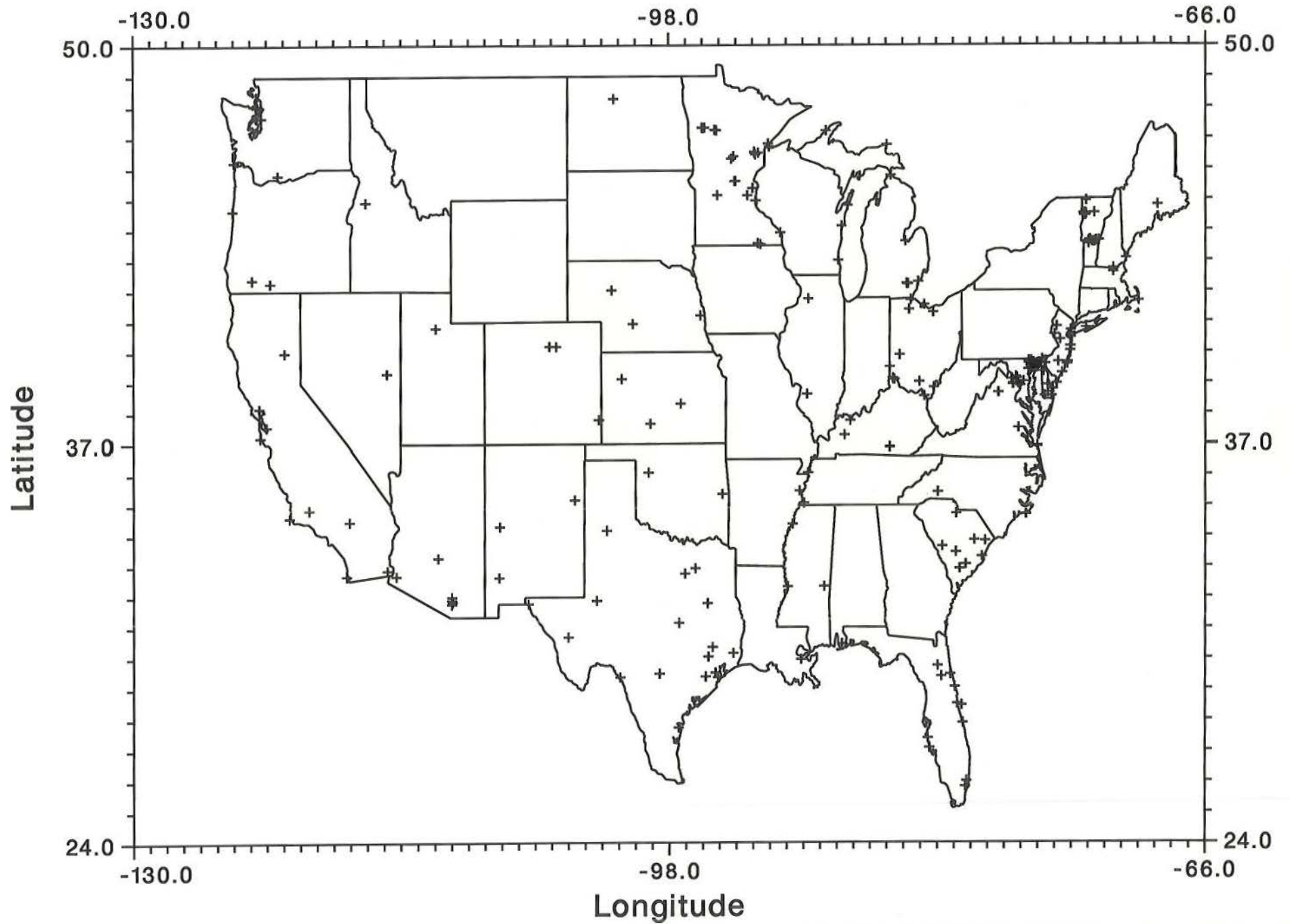* = Experimental solution taylored to the 1 cm (1 σ) GPS in these states

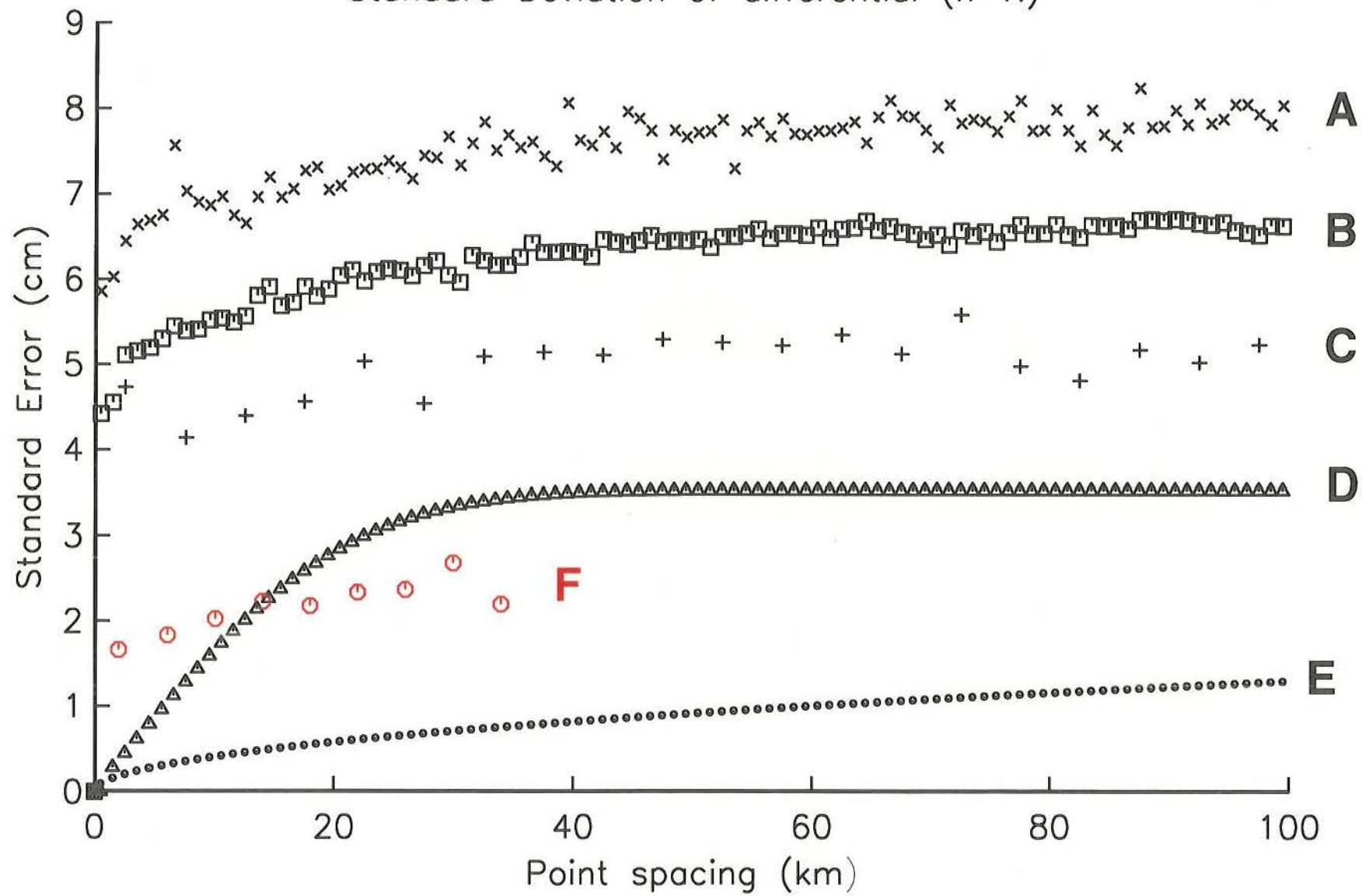# DIFFERENTIAL GPS-DERIVED ORTHOMETRIC HEIGHT ACCURACY

σ **can be reduced through:**

- Multiple ties (4 ties = half the σ of a single tie)

- Better knowledge of the geoid (i.e. Baltimore county)

Local (<5 km) σ is hard to know due to lack of special studies

pairs.0.0__0.5km.latlon

Standard Deviation of differential (h−N)

CONCLUSIONS

- GEOID99 has 4.6 cm RMS absolute agreement with GPS/BM (GEOID96 was 5.5 cm)

- Short lines (< 5 km) are hard to evaluate due to lack of data

- Medium lines (5-40 km) are 4-10 ppm with single-ties

- Longer lines (40+ km) may be influenced by leveling error

- Establishing NAVD 88 heights from GEOID99 and GPS can be improved if multiple ties are used and the geoid is better known

GEOID99 Availability

WWW (Sept. 30):
    http://www.ngs.noaa.gov/GEOID/geoid99.html

CD-ROM (Mid-October):
    Information Services Branch
    NOAA/National Geodetic Survey, N/NGS12
    1315 East-West Highway, Station 9202
    Silver Spring, MD 20910-3282
    voice: 301-713-3242
    fax: 301-713-4172