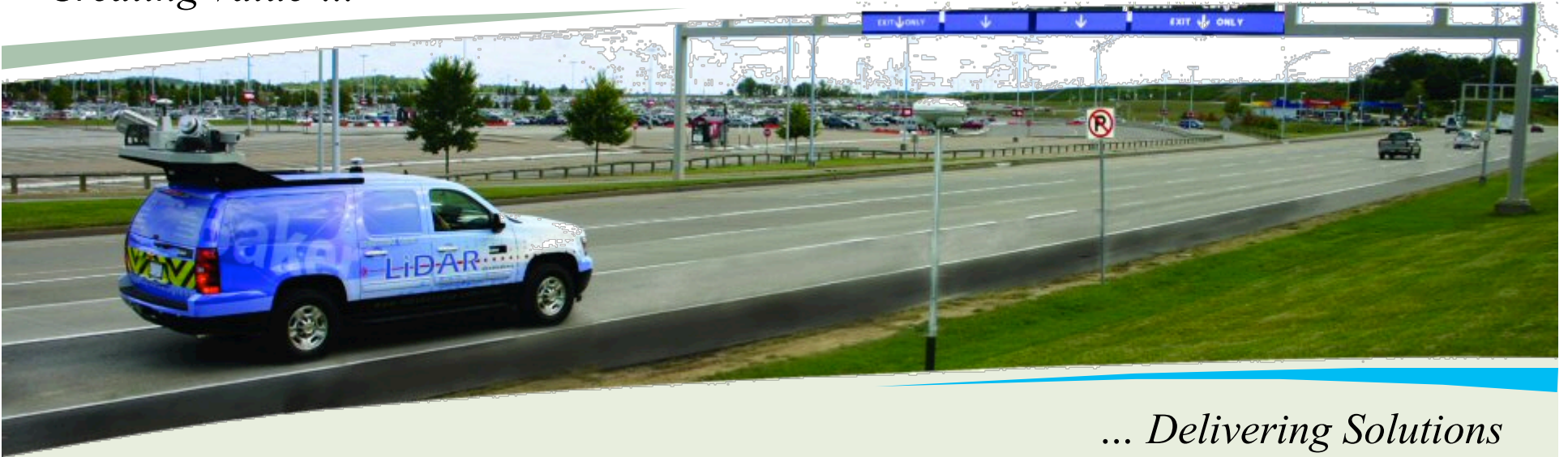


Creating Value ...



... Delivering Solutions

Geoid Models and the Future of Bench Marks

California Real-Time Network (CTRN) Workshop
September 28th & October 5th 2012

Presenter: Gregory A. Helmer

Baker

Modernize the Geopotential (“Vertical”) Datum

NGS 10-Year Plan:

“The era of using geodetic leveling for continent-scale vertical datum definition comes to an end.”



Force and Potential

Strong Nuclear	(1)
Electromagnetic	(7×10^{-3})
Weak Nuclear	(1×10^{-6})
Gravity	(6×10^{-39})

First Law of Thermodynamics: Energy is Conserved

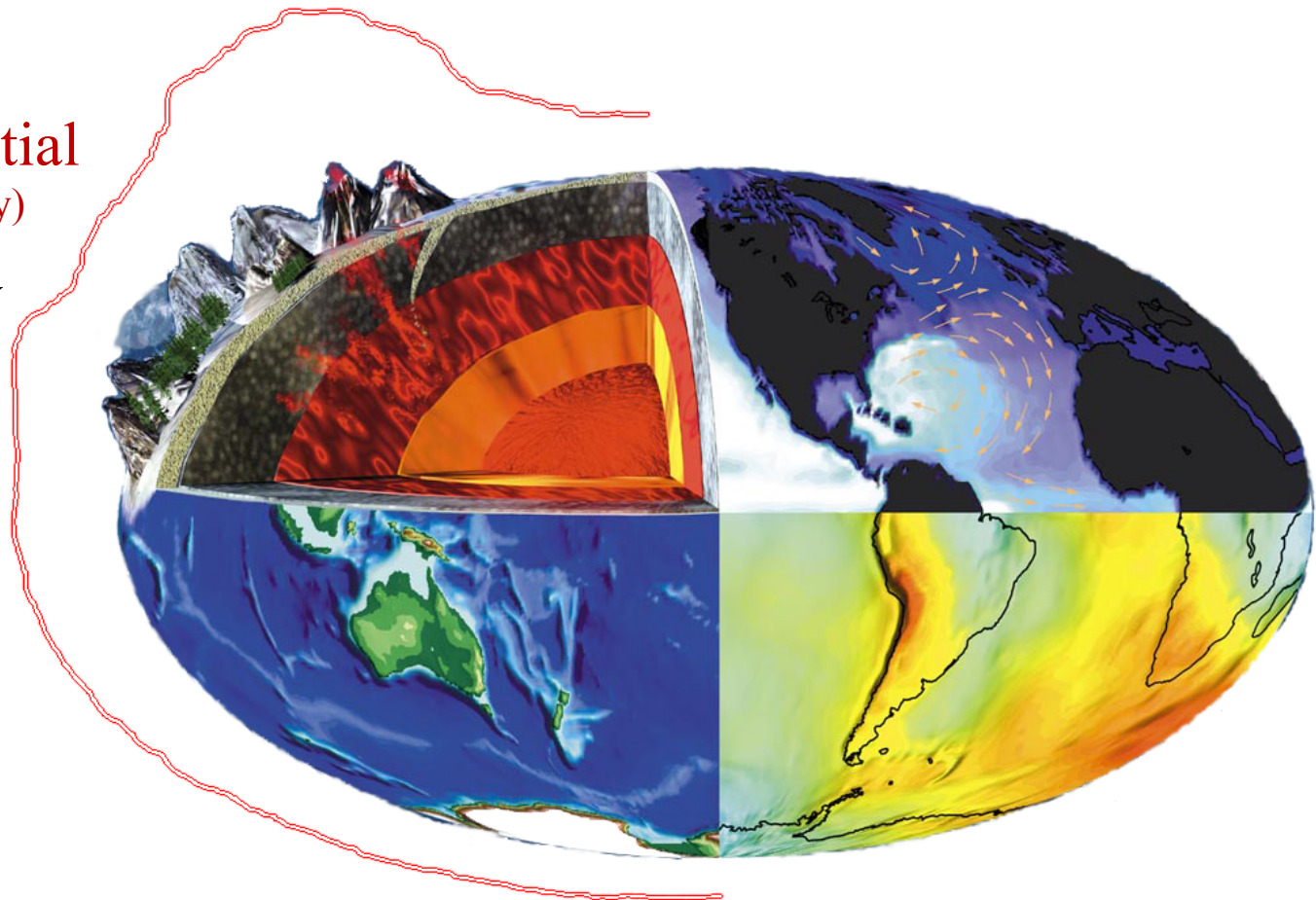
Second Law: Energy Flows from Higher to Lower Potential

Equipotential
(Work ~ Energy)

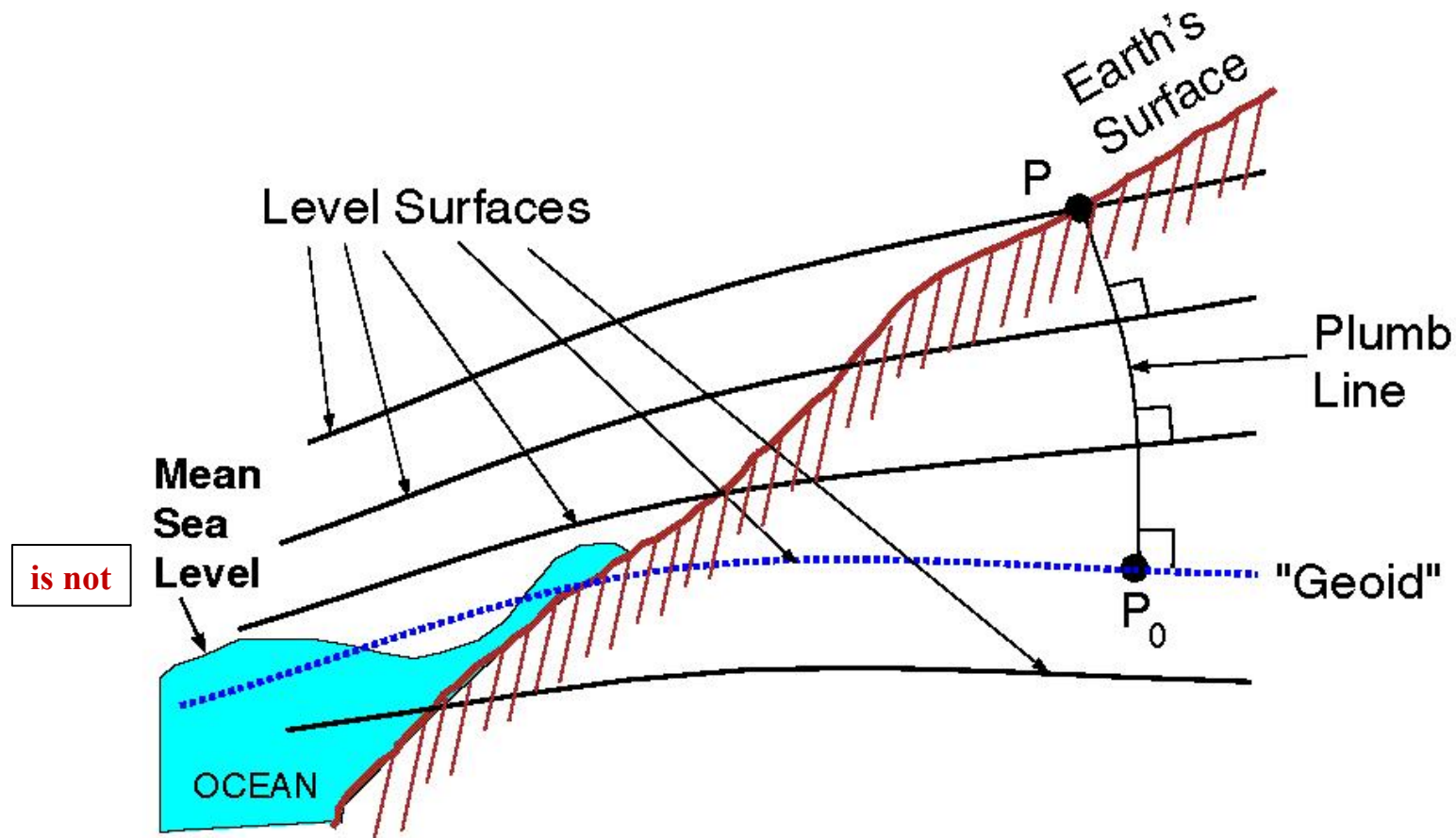
Not Equal Gravity

Geopotential

Number (Kgal meter)
 \approx Orthometric Htg. meters



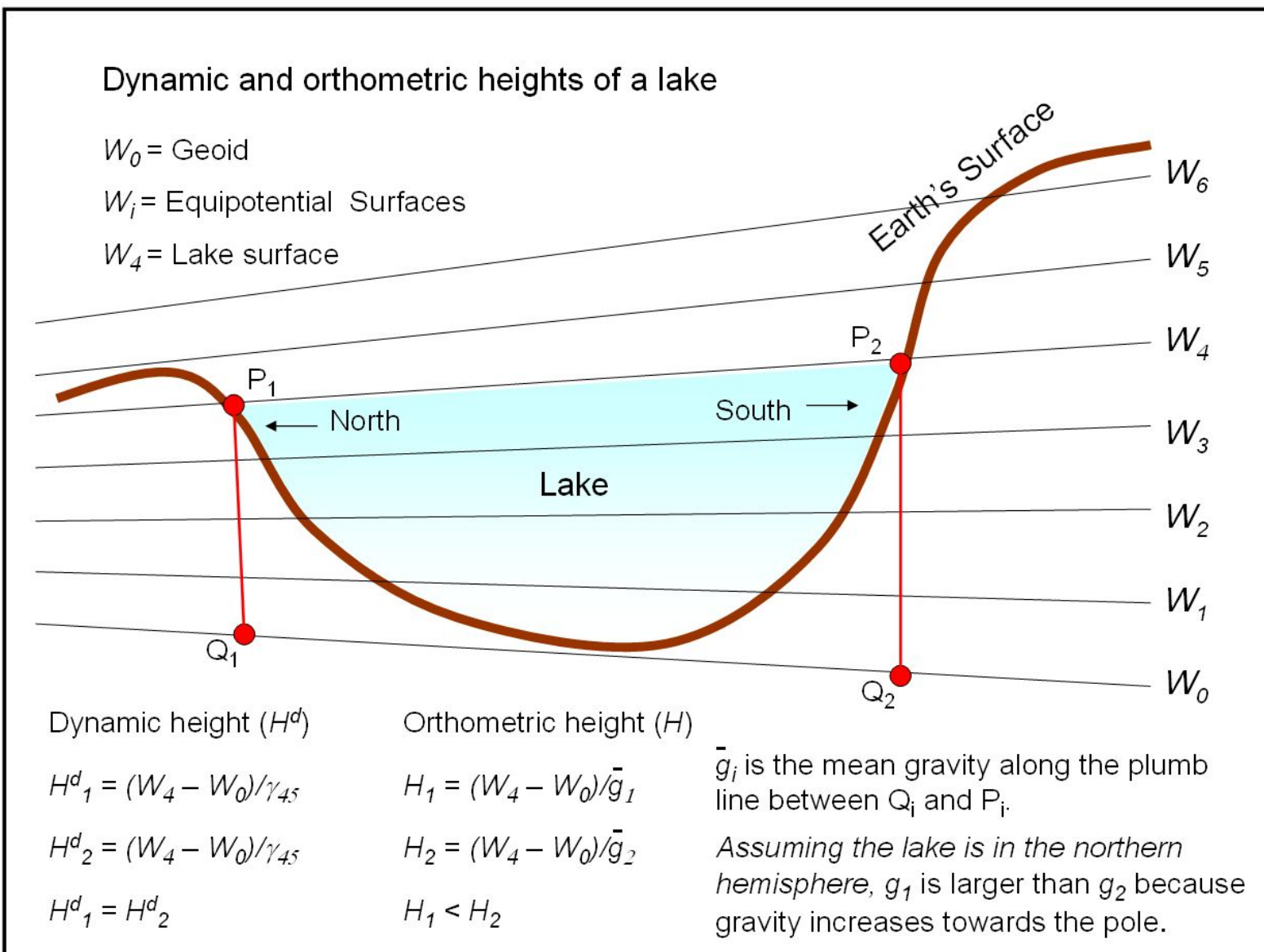
Geometric (Measureable) Heights



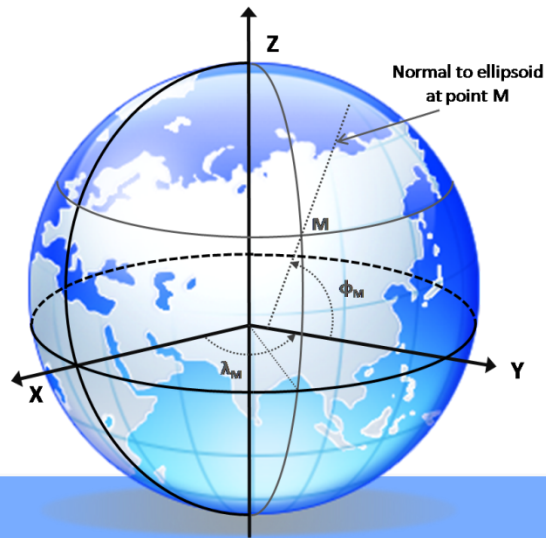
Level Surface = Equipotential Surface

H (Orthometric Height) = Distance along Plumb line (P_0 to P)

Orthometric and Dynamic Heights



Equipotential Ellipsoids



	WGS84	GRS80
Semi-major axis = Equatorial Radius = a	6,378,137 m	6,378,137 m
Geocentric gravitational constant, including mass of the atmosphere = GM	$3,986,005 \times 10^8 \text{ m}^3/\text{s}^2$	$3,986,005 \times 10^8 \text{ m}^3/\text{s}^2$
Angular velocity of rotation = ω	$7,292,115 \times 10^{-11} \text{ s}^{-1}$	$7,292,115 \times 10^{-11} \text{ s}^{-1}$
Dynamical form factor = J_2		$108,263 \times 10^{-8}$
Normalized second degree zonal gravitational coefficient = $C_{2,0}$	$-484.16685 \times 10^{-6}$	

Global Geoid

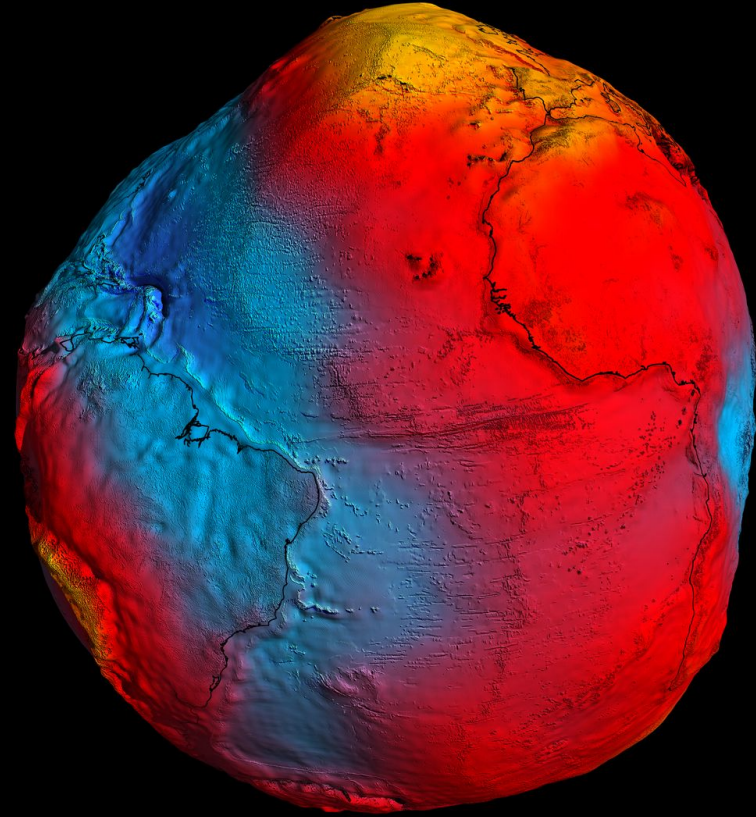
+100 to -100 meters

**Gravity Field and Steady-State
Ocean Circulation Explorer
(GOCE) ESA 2009**

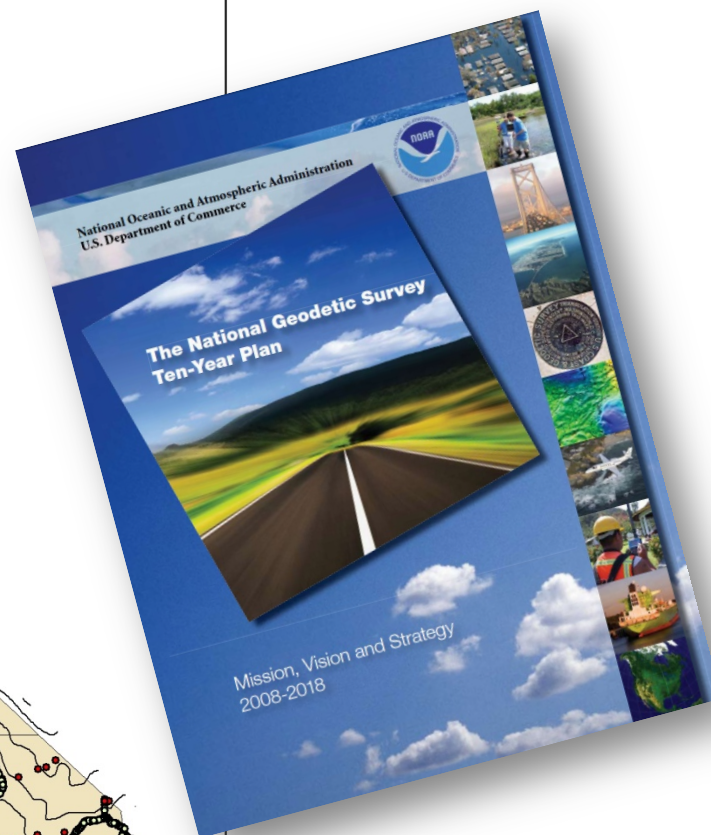
0.00001 PPM (10^{-13})

RMS 4.6cm @ 100km

**Gravity Recovery
And Climate Experiment
(GRACE) NASA 2002**



Follow the Money



15,912 “Adjusted” Heights
\$2M/Year to Maintain

PRC Chapter 5

California Orthometric Heights of 1988

Protected Terminology

Leveled COH88 Height

Derived COH88 Height (GNSS)

- NGS Geoid
- May Include Corrector Surface

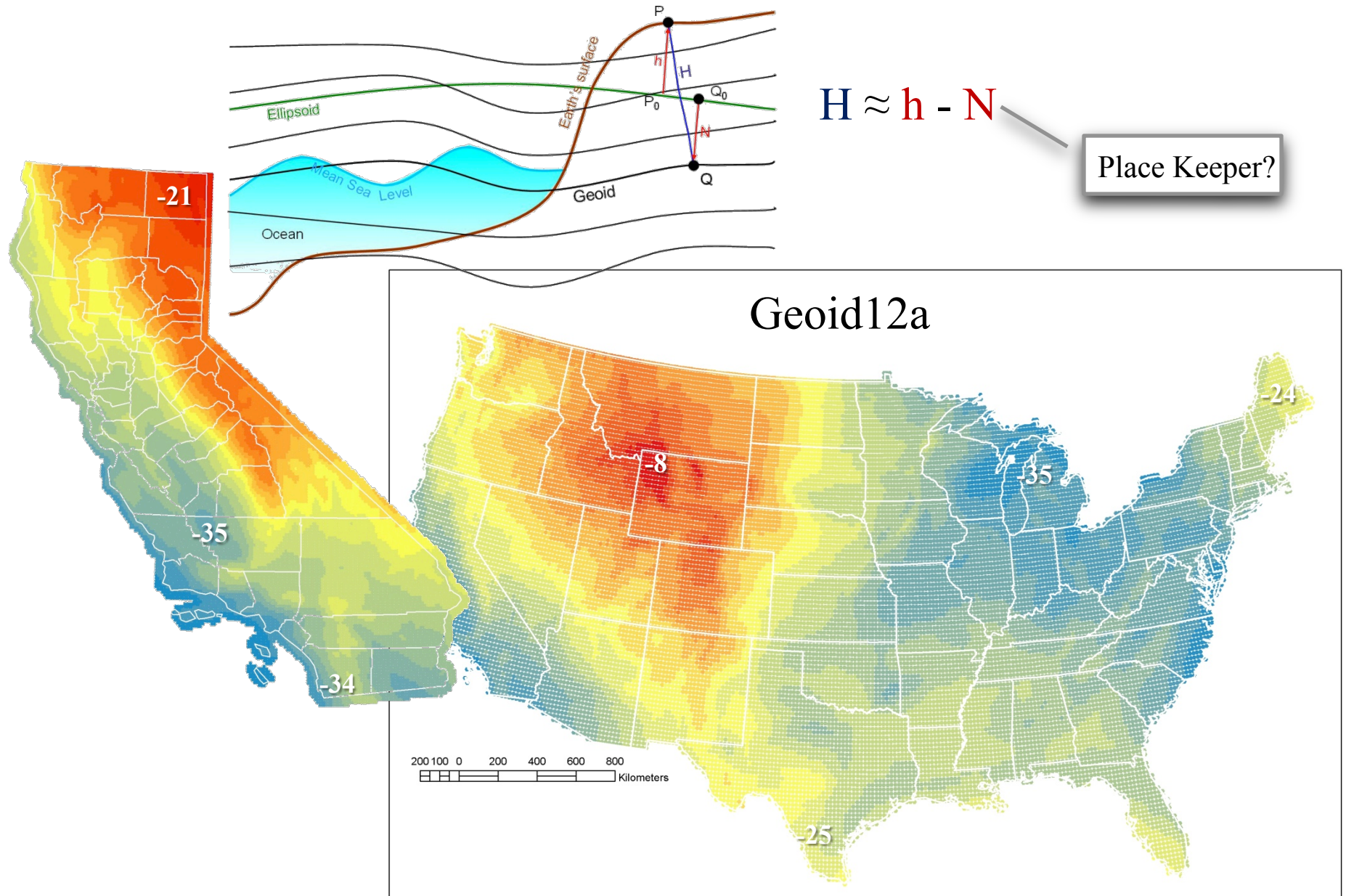
Epoch Date of
Controlling Station(s)

Control must comply with Section 8813

- CSRN or CSRN Equivalent

8896. The accuracy of derived COH88 values may be improved by applying a "local orthometric height correction" to the geoid height determined from the latest, applicable geoid model published by NGS.

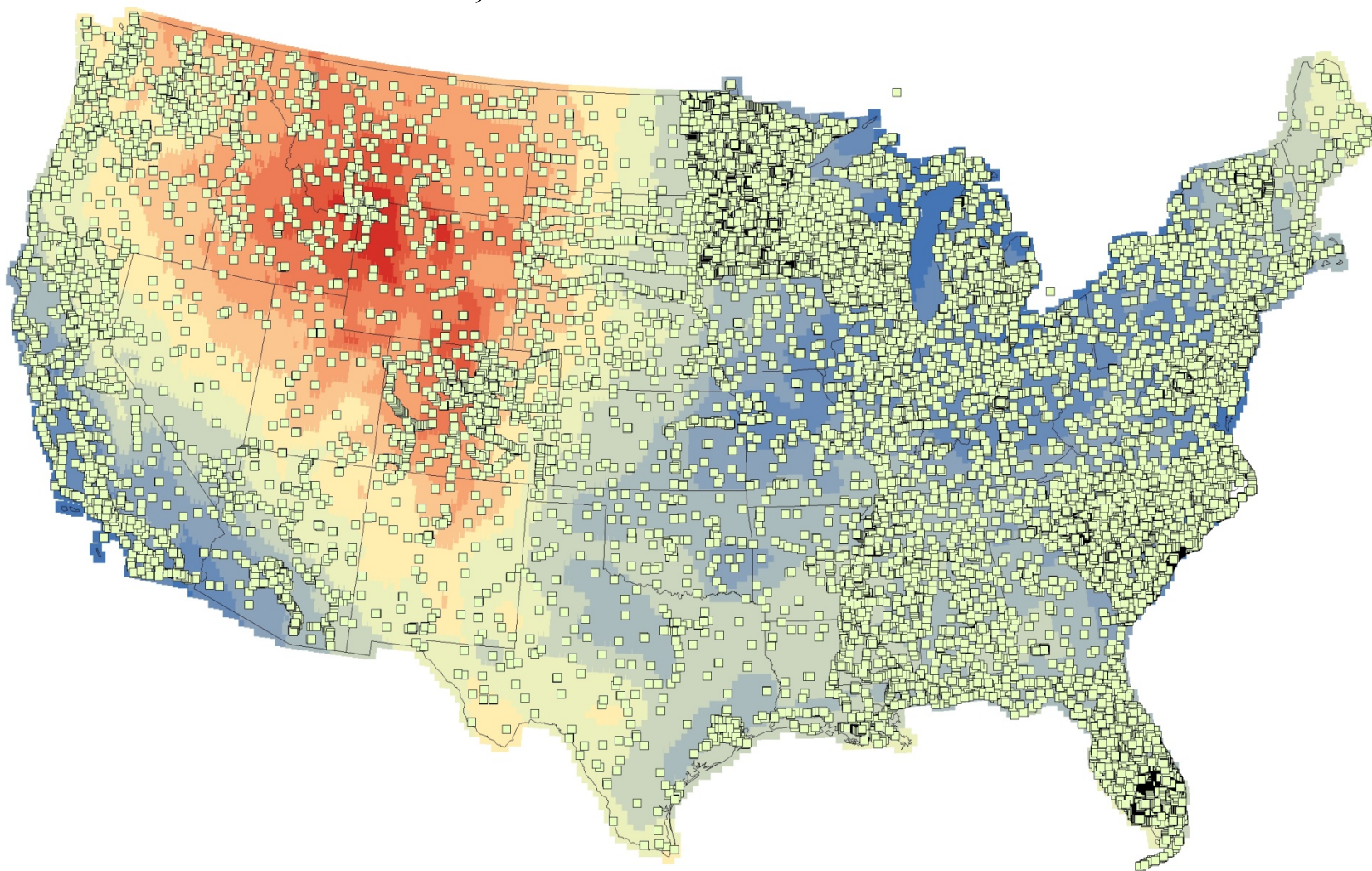
Most Current National Geoid



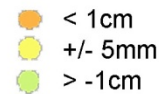
Hybrid Collocated Geoid

Geoid12a:

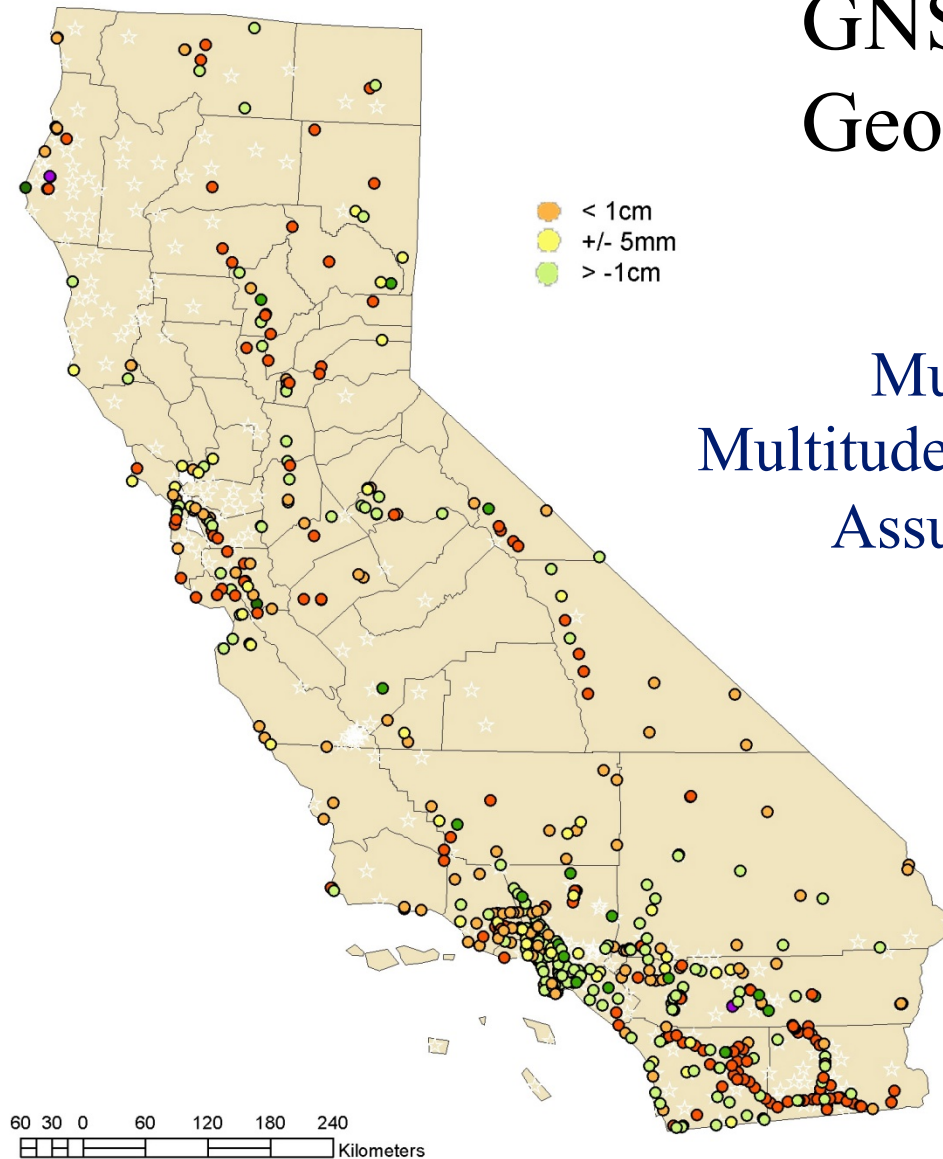
24,871 GPS NAVD88 Bench Marks



GNSS-Derived Heights Geoid12a

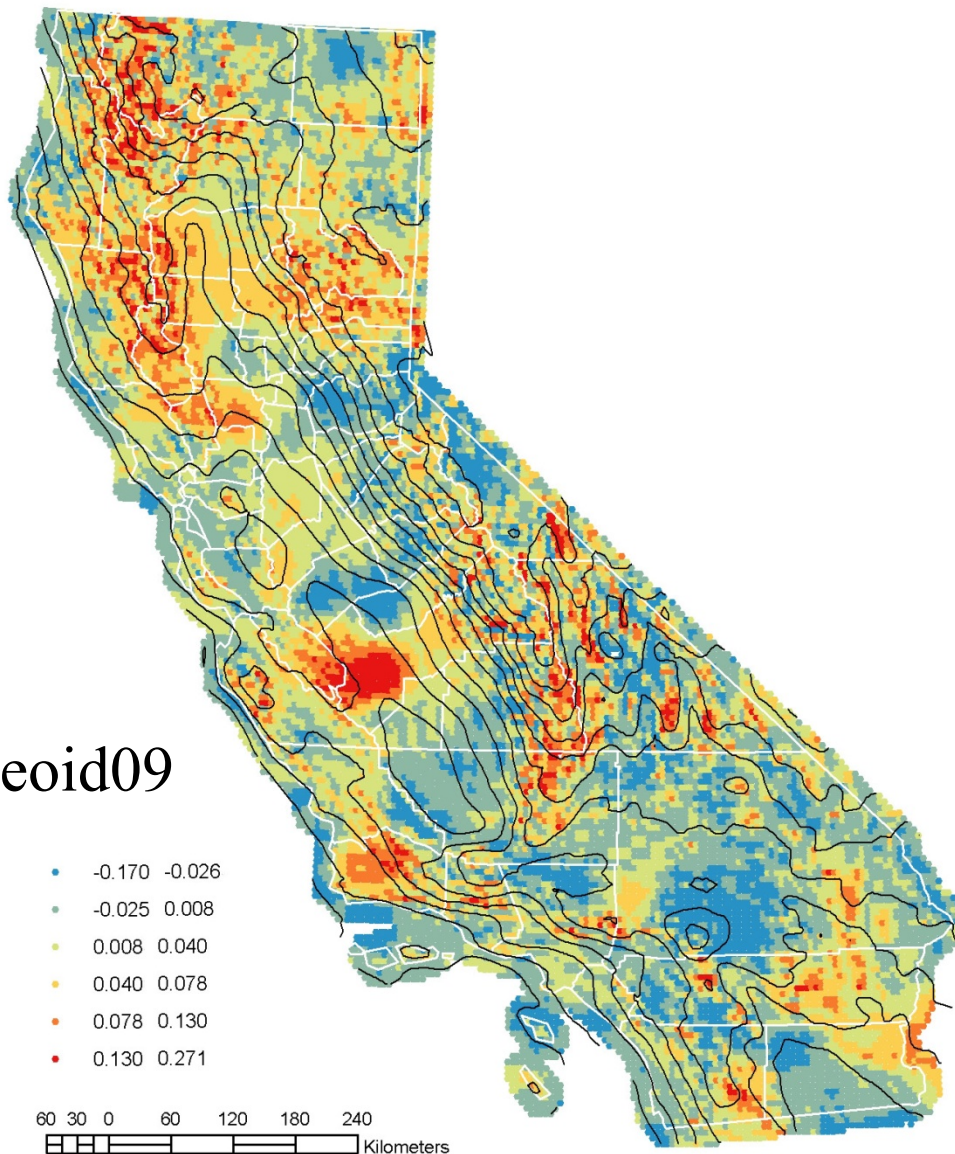


Multiple Network Solutions
Multitude of Observation Methods
Assumes NAVD88 is Correct



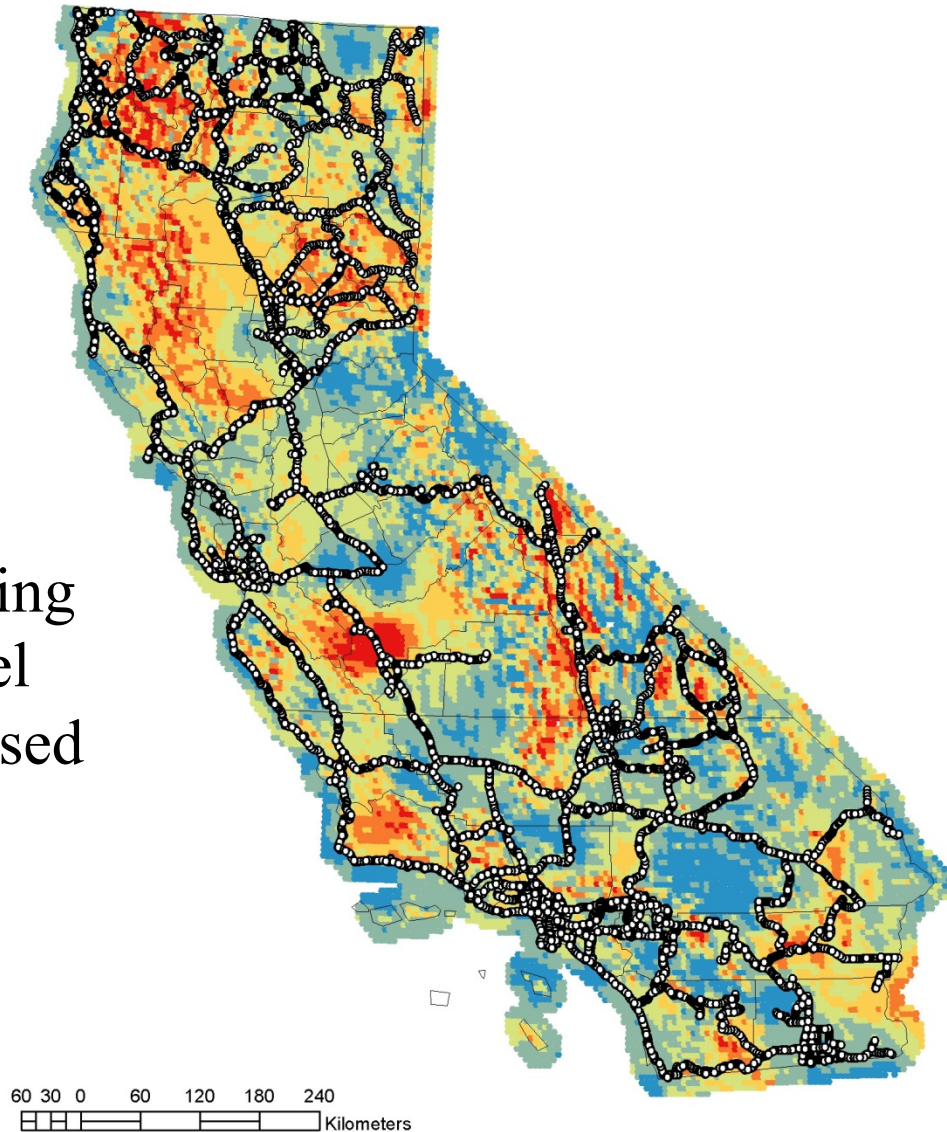
Geoid Changes, Physical and Analytical

Geoid12a minus Geoid09

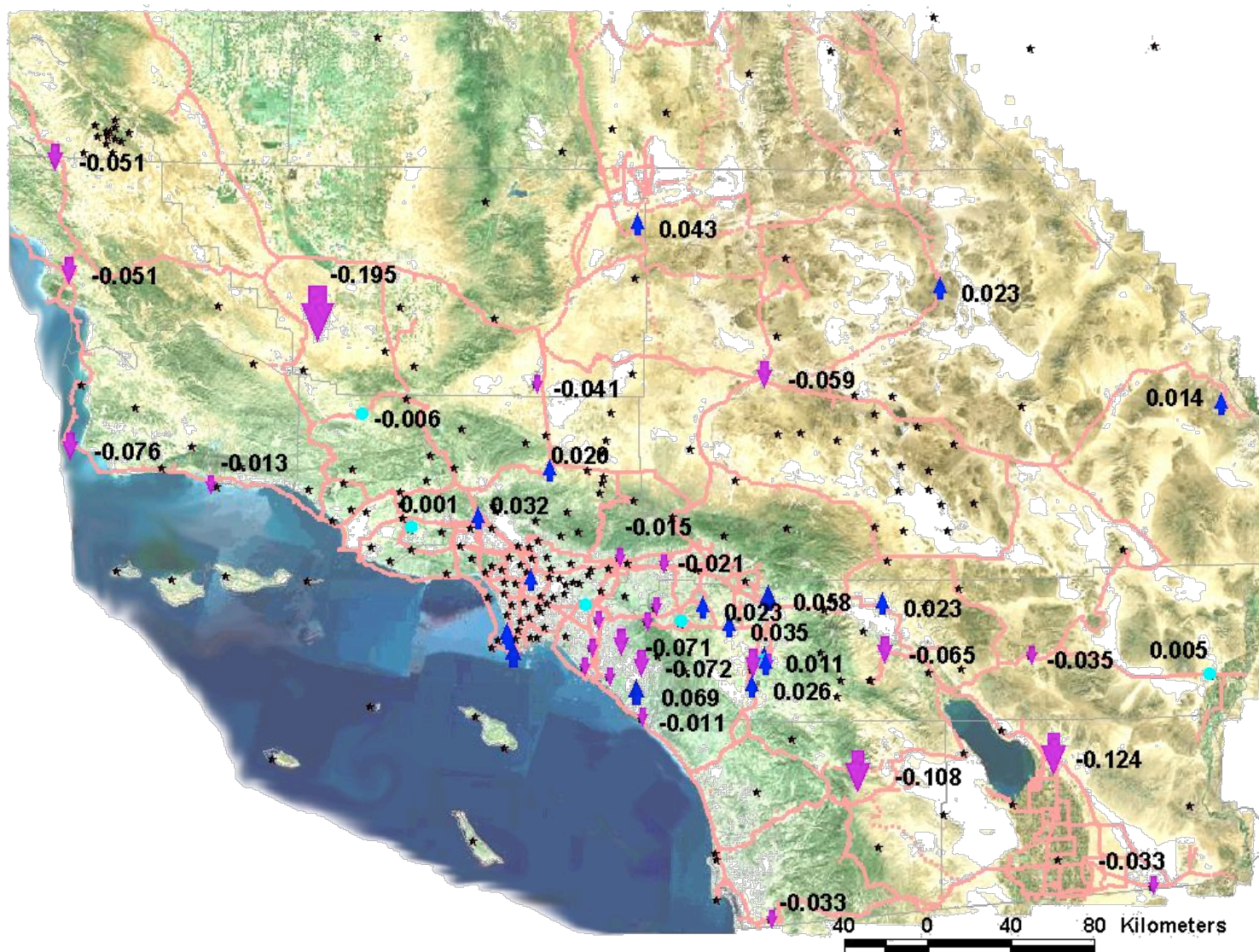


Orthometric Height Correction

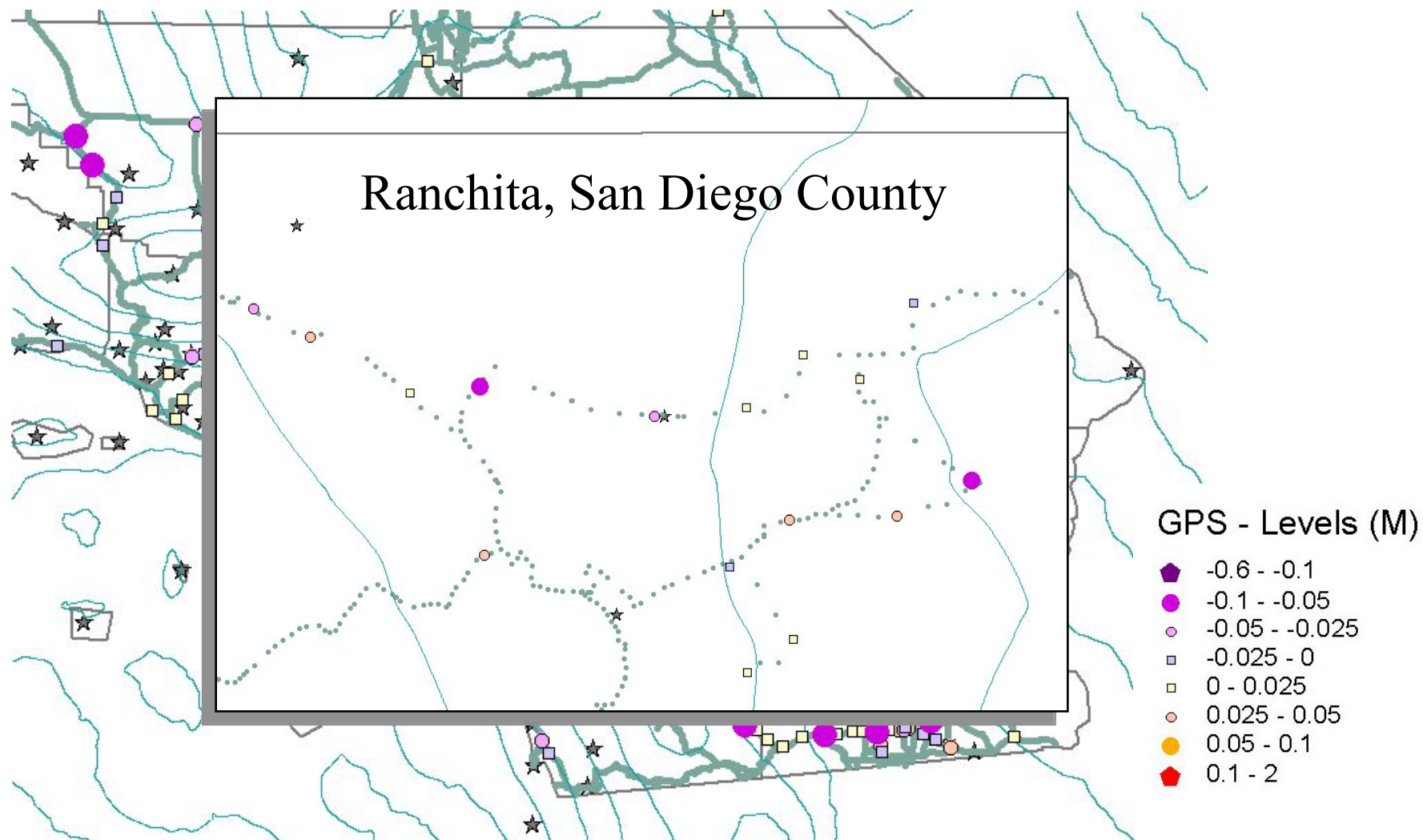
Original NAVD88 Leveling
Corrected for non-parallel
equipotential surfaces based
upon the 1991 database.



Southern California CORS Leveling

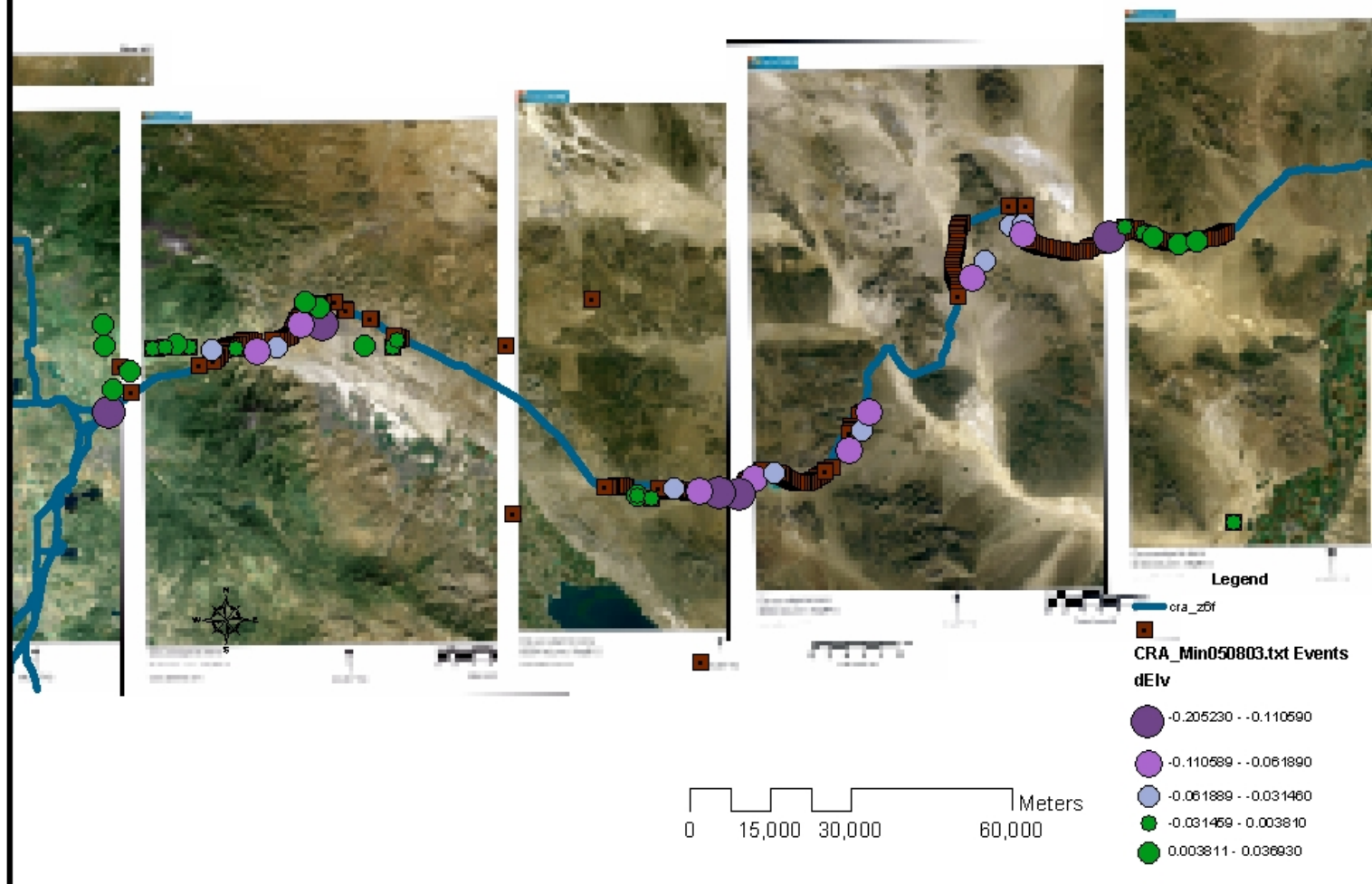


GNSS-Derived Heights

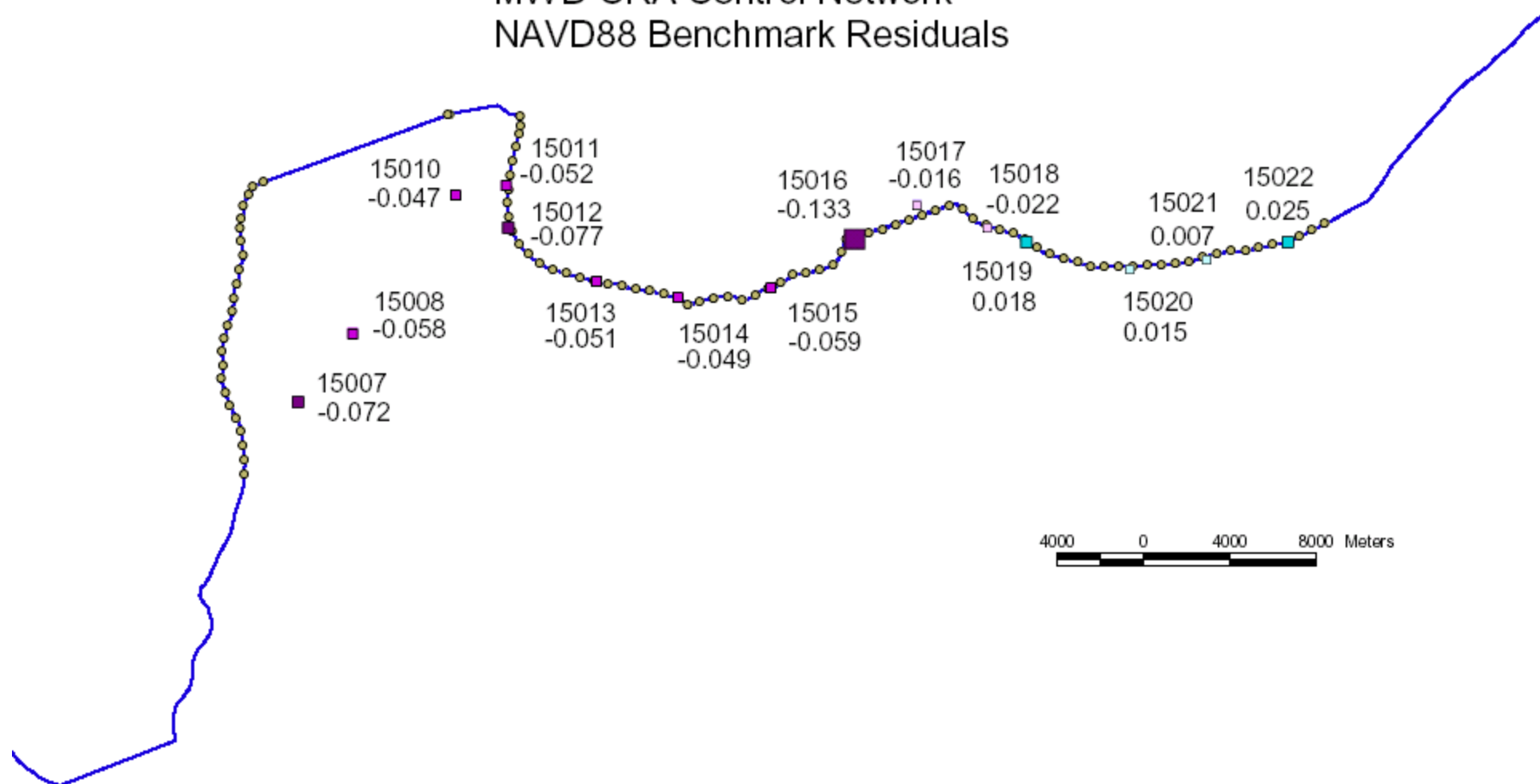


Colorado Aquaduct GPS Control Survey

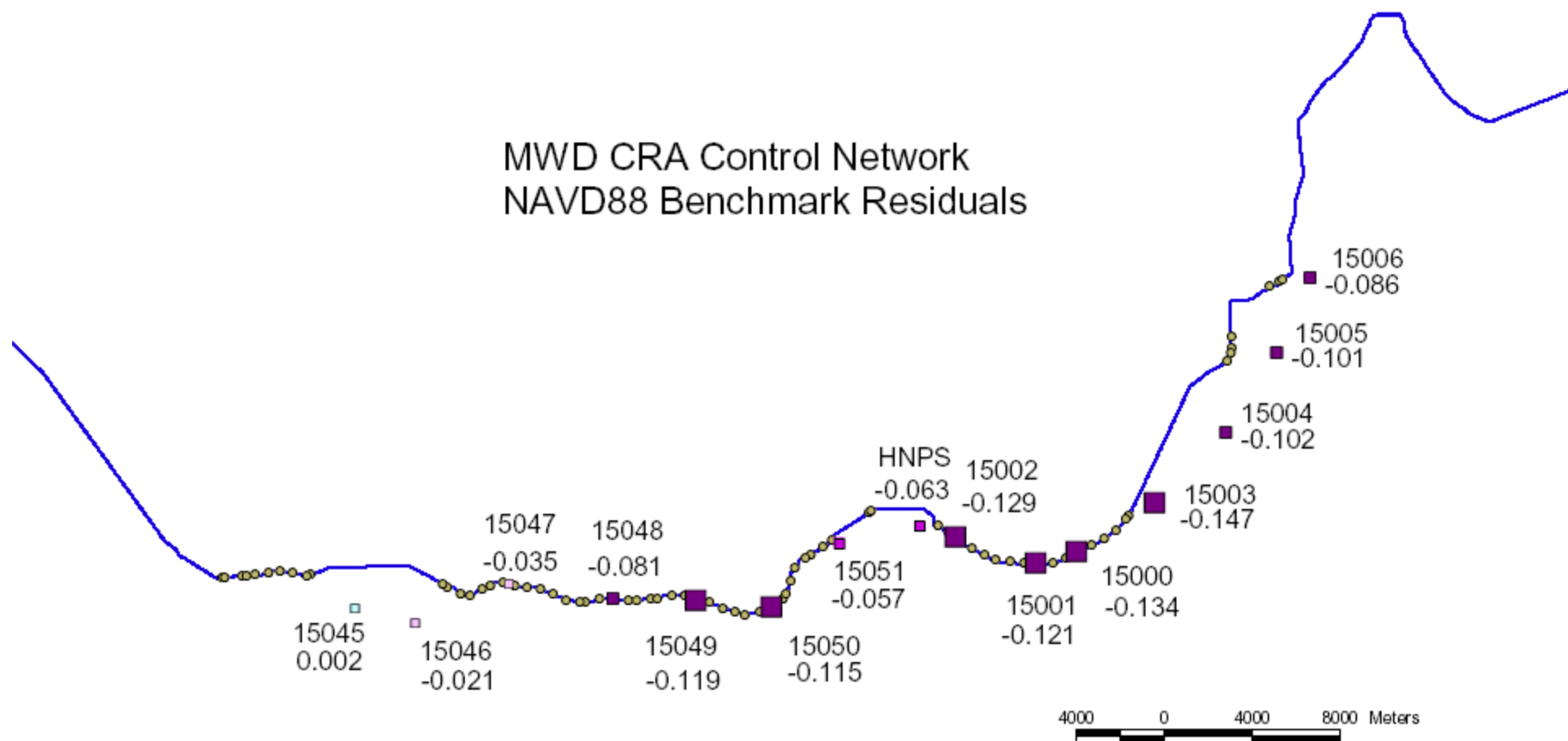
NAVD88 BENCHMARK RESIDUALS



MWD CRA Control Network NAVD88 Benchmark Residuals

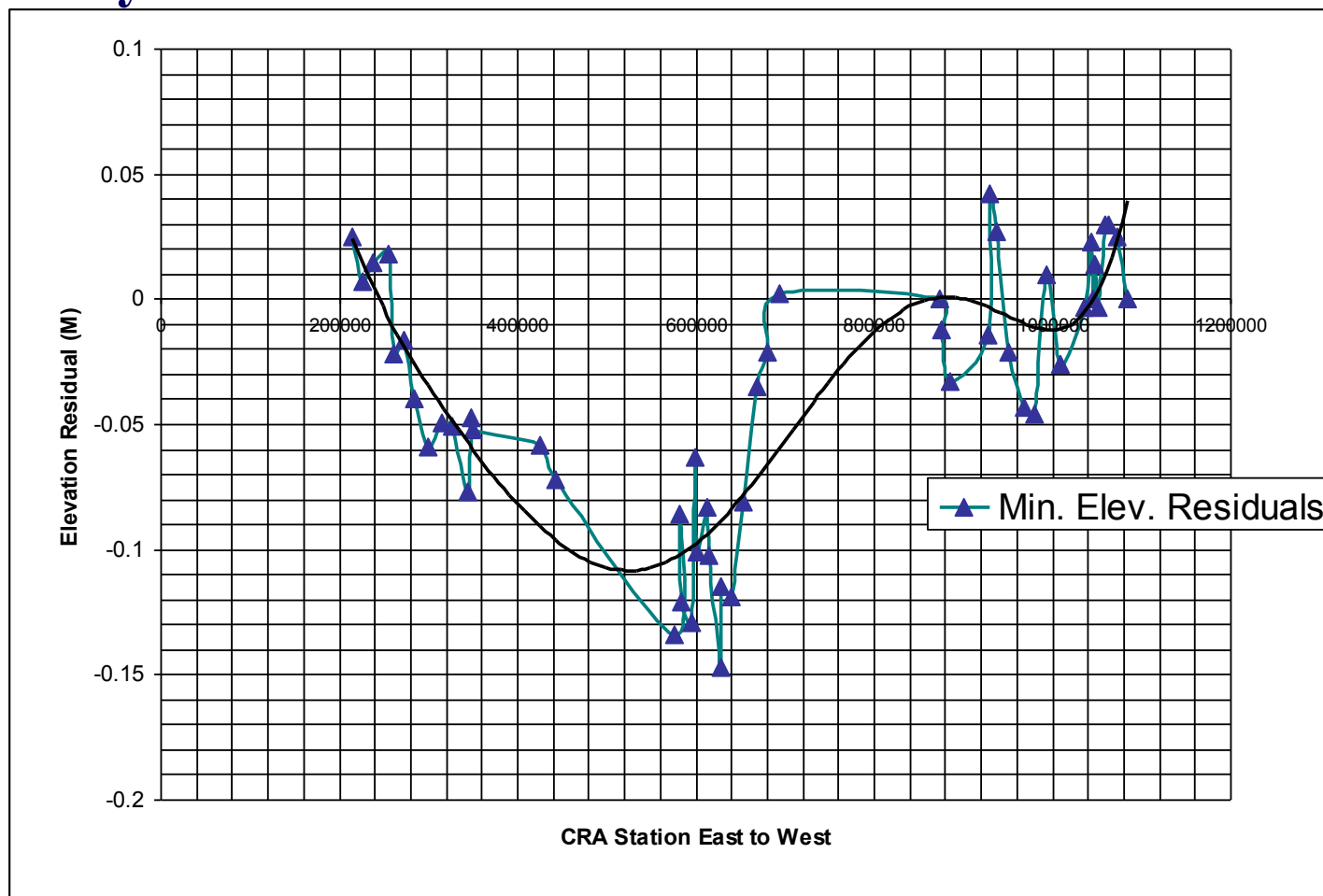


MWD CRA Control Network NAVD88 Benchmark Residuals



Geoid Corrector

Polynomial Curve Fit

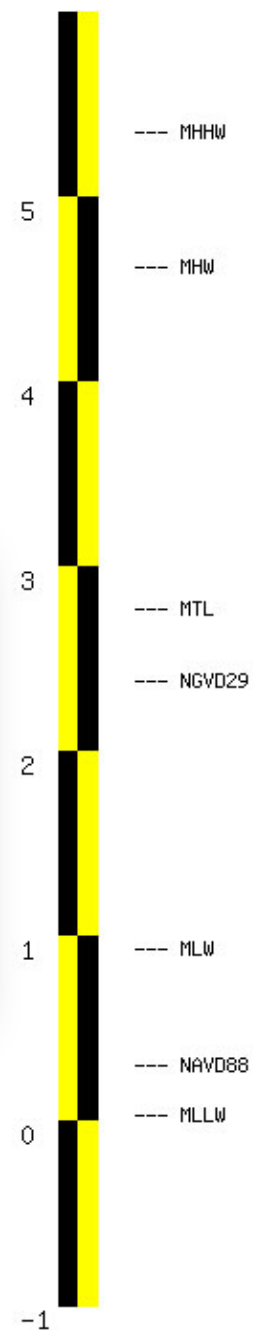
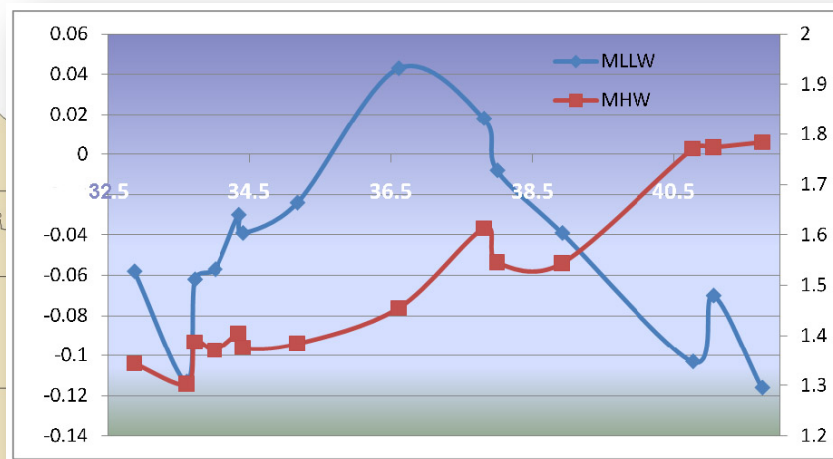
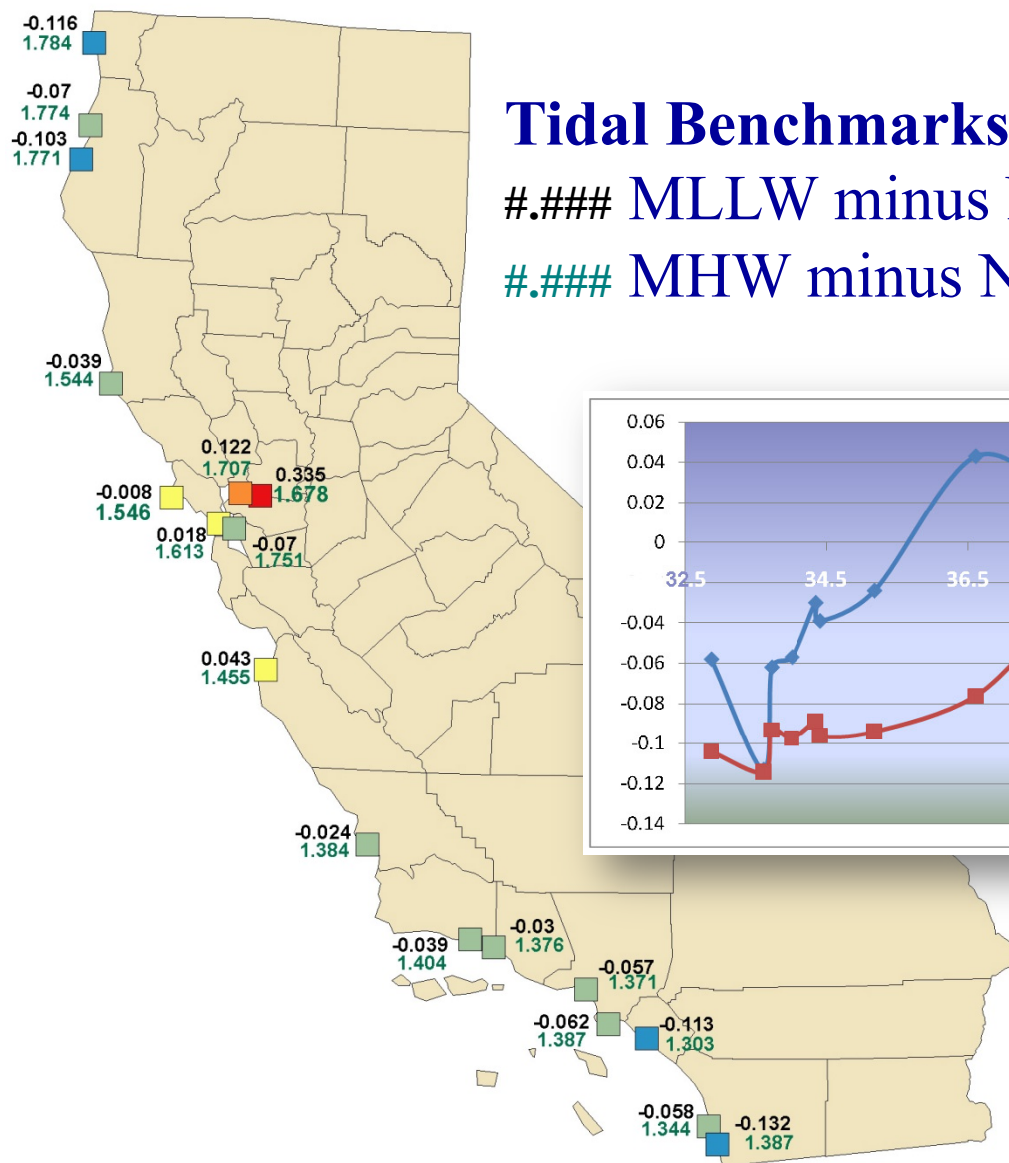


Tidal Datum

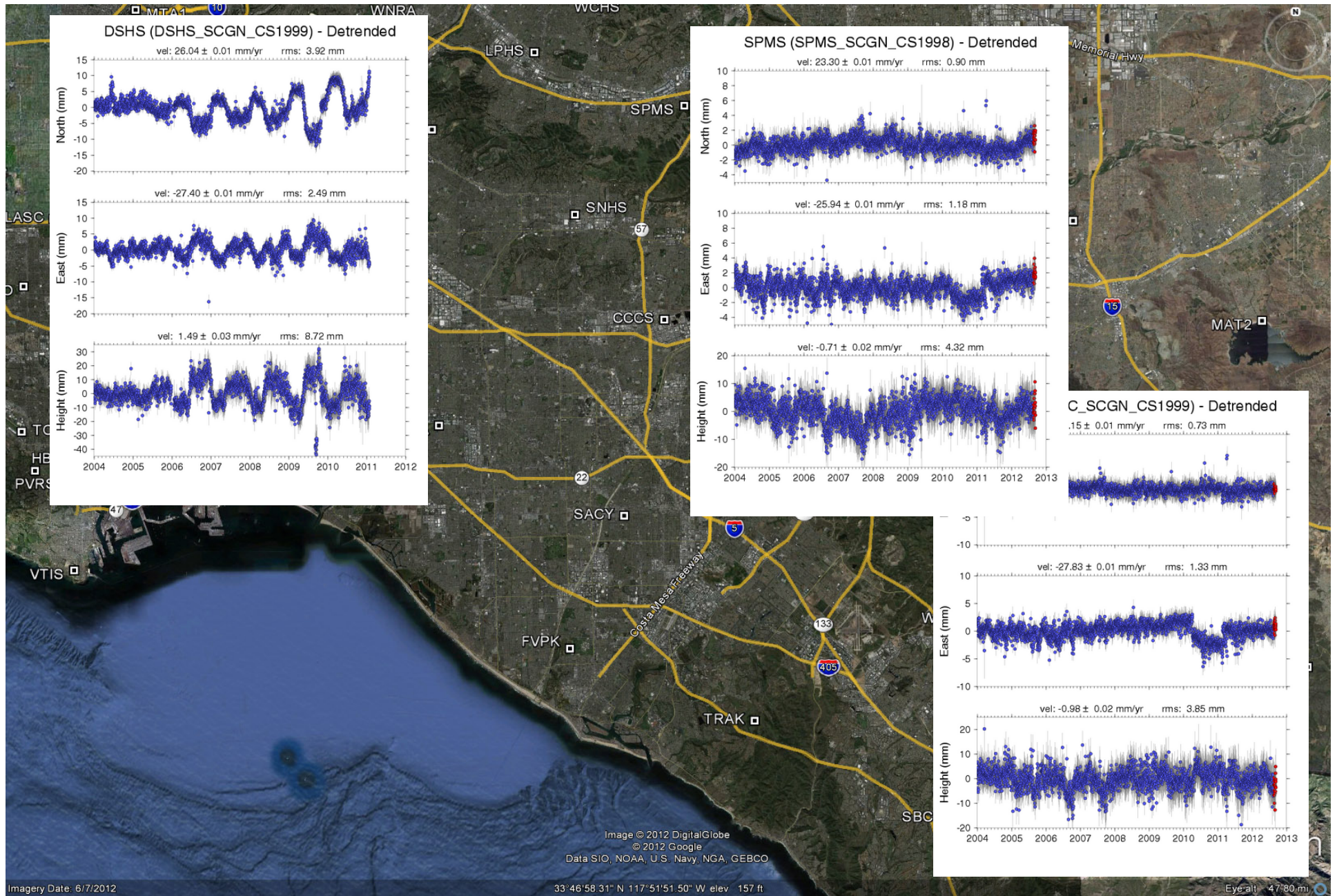
Tidal Benchmarks

MLLW minus NAVD88 meters

MHW minus NAVD88 meters



Epoch Dating Heights



Epoch Dating Heights

