New Datums for the Nation: Modernizing the United States National Spatial Reference System

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The National Geodetic Survey

The mission of the National Oceanic and Atmospheric Administration's (NOAA) National Geodetic Survey (NGS) is "to define, maintain and provide access to the National Spatial Reference System (NSRS) to meet our nation's economic, social, and environmental needs." NSRS is the nation's system of latitude, longitude, elevation, and related geophysical and geodetic models and tools, which provide a consistent spatial framework for the broad spectrum of positioning requirements related to geospatial data (Fig. 1). Modern technological developments (notably Global Navigation Satellite Systems (GNSS)), the dynamic nature of Earth, and today's demanding user accuracy requirements necessitate that NGS modernize the NSRS, which has continued to evolve throughout the 210-year history of NGS and its ancestral organizations. Consequently, a comprehensive NSRS makeover is currently underway, to be completed in 2022 (anticipated) and delivered through a new generation of horizontal and vertical datums (reference frames), replacing the North American Datum of 1983 (NAD83) and the North American Vertical Datum of 1988 (NAVD88) and featuring unprecedented accuracy, repeatability, and efficiency of user access.

This effort is guided in part by the NGS "Ten-Year Strategic Plan: 2013–2023," which can be found here: www.ngs.noaa.gov/web/news/Ten_Year_Plan_2013-2023.pdf.

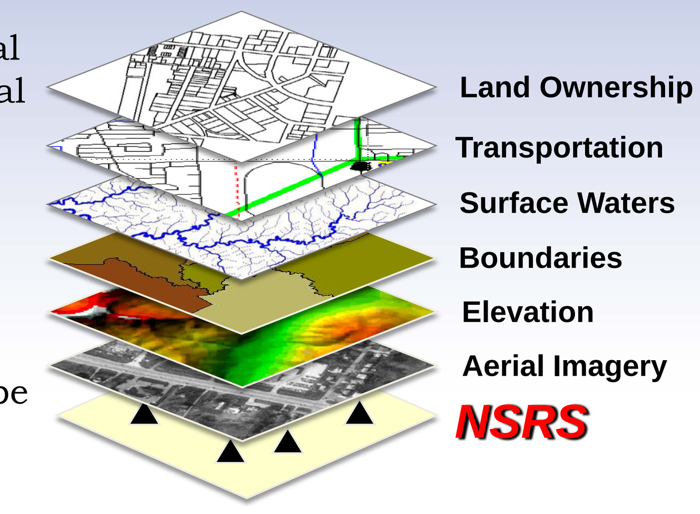


Figure1. Typical geospatial data layers and the National Spatial Reference System (NSRS), the foundational layer which provides a common horizontal and vertical spatial coordinate reference and allows data from disparate sources to be analyzed in a consistent spatial framework.

Current NSRS Status & Motivation for New Datums

Figure 2. CORS site P028 (owned/operated by UNAVCO, www.unavco.org); CORS such as this help define the geometric component of today's NAD83 and the new geometric datum.

The primary user elements of today's NSRS are NAD83 (for latitude, longitude, and ellipsoid height; aka geometric coordinates), NAVD88 (for orthometric height; aka elevation), and GEOID12B (a hybrid geoid model relating NAD83 ellipsoid heights with NAVD88 orthometric heights).

NAD83: The definitional foundation of the geometric component of today's NSRS is a nationwide network of some 2000 GNSS Continuously Operating Reference Stations (CORS) (Fig. 2). High accuracy site coordinates and velocities are published on both NAD83 (2011) epoch 2010.00 and the International GNSS Service 2008 (IGS08) epoch 2005.0. Some 80,000 passive control stations, positioned through network adjustment to the CORS framework of their processed GPS observations, complete the geometric realization of today's NAD83 datum. NAD83 suffers from being non-geocentric by about 2.2 m, resulting in a substantial disconnect from the commonly used global reference frames, including IGS08, the International Terrestrial Reference Frame (ITRF) and the World Geodetic System of 1984 (WGS84). Passive stations also suffer from having coordinates based on limited-duration and episodic occupations.

NAVD88: The high-accuracy orthometric height component of the NSRS is defined primarily through a nationwide network of differentially leveled passive control stations, surveyed over many decades (Fig. 3). Ongoing maintenance of the NAVD88 passive network is impractical, and it is known to be biased with respect to today's understanding of the gravitational potential most closely aligned with mean sea level (zero elevation).

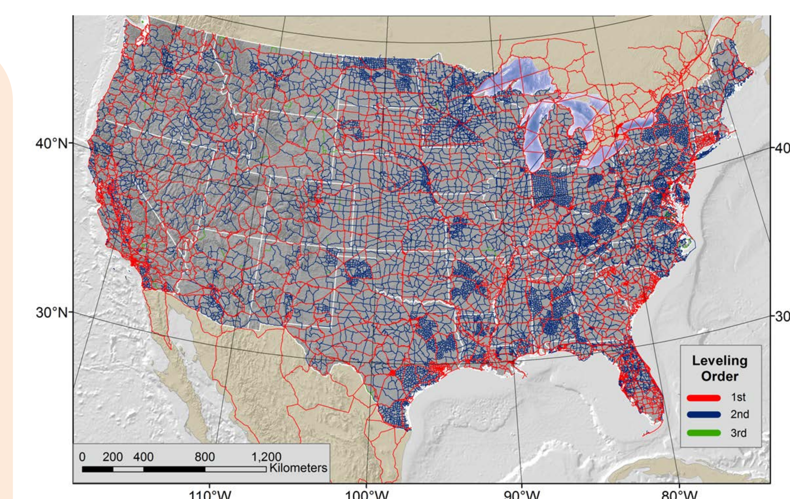
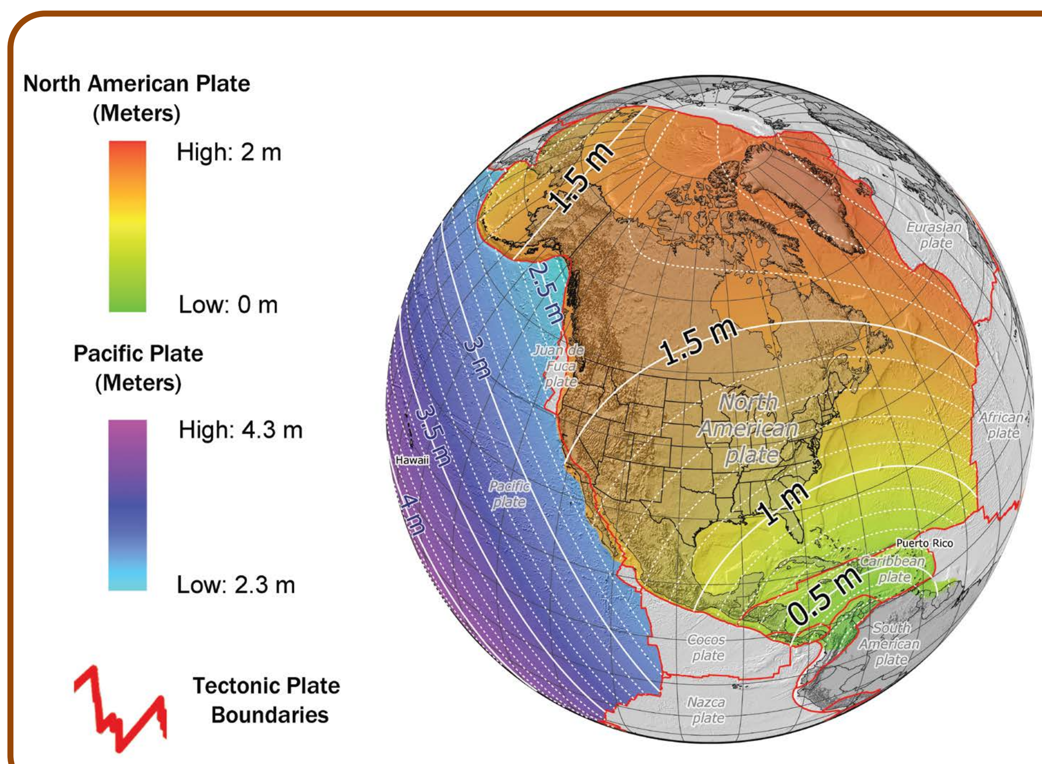


Figure 3. NAVD88 CONUS level network, illustrating the scope of the traditional differential leveling effort on a nationwide scale. Map by Brian Shaw, NGS.

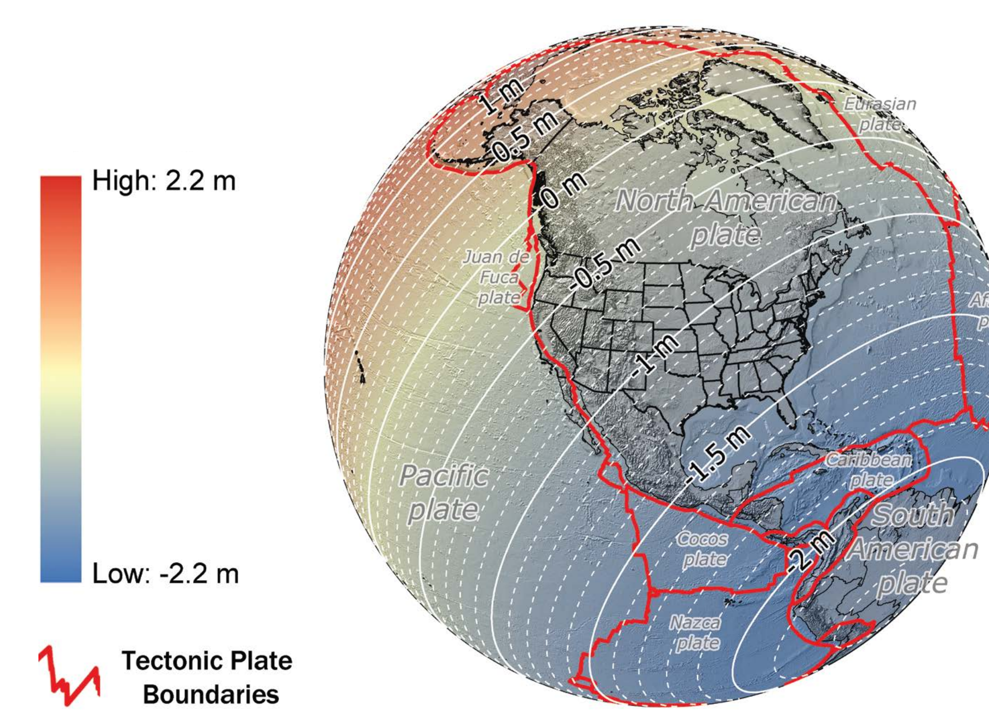
New Geometric Datum



The new geometric datum, replacing NAD83, will be CORS-based, with station coordinates/velocities published in both the then-current international reference frame (likely the International Terrestrial Reference Frame) and the new national datum. New datum definition details (including naming) are still evolving and are being informed by ongoing input from NGS product users, federal and international partners, and pertinent professional organizations, often through collaboration events such as geospatial summits. See Figs. 4 and 5 for plots of anticipated change between NAD83 and the new geometric datum. NGS will provide transformation tools to relate the current, previous, and new datums, in support of user adoption of the new datums.

Figure 4. Approximate anticipated change in horizontal position, comparing NAD83 with the new geometric datum. Note the impact of plate tectonic motion.

Figure 5. Approximate anticipated change in ellipsoid height, comparing NAD83 with the new geometric datum. Both maps by Michael Dennis & Brian Shaw, NGS.



New Geopotential / Vertical Datum

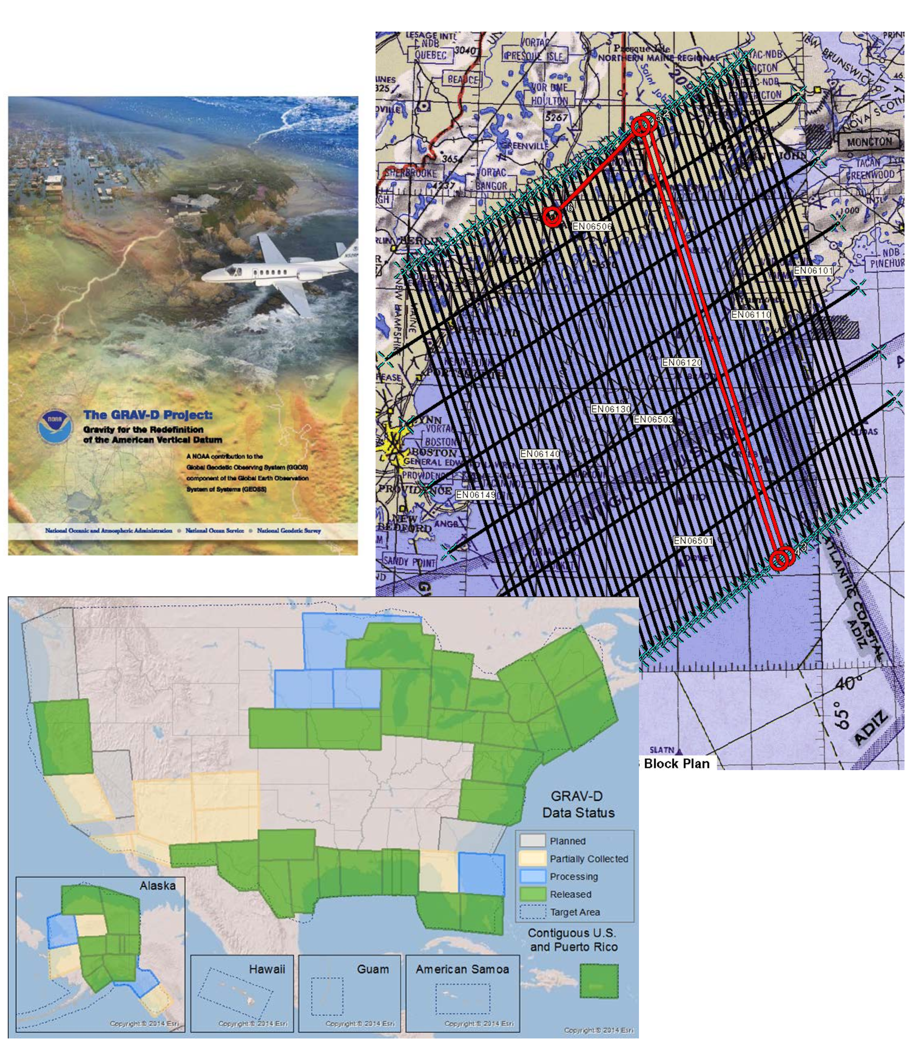


Figure 6. GRAV-D typical airborne gravity data collection flight pattern (upper right) and late 2016 collection status (bottom). Just over one-half of the nation has been collected.

The new geopotential/vertical datum, replacing NAVD88, will be accessed through a combination of user-collected GNSS data and a high-accuracy national gravimetric geoid model, which will be built from an ambitious ongoing NGS airborne gravity data collection program - Gravity for the Redefinition of the American Vertical Datum (GRAV-D) (Fig. 6). The characterization of Earth's gravitational field, built from GRAV-D, will define the zero elevation surface, thereby supporting conversion from a GNSS-measured ellipsoid height to an orthometric height (or elevation) (Fig. 7). The goal of the new vertical datum is to support achievable accuracy of 2 cm in elevation, anywhere in the nation, without need to access passive control. See Fig. 8 for a plot of the approximate anticipated change in orthometric height between NAVD88 and the new vertical datum. This plot also indicates the approximate bias that currently exists in NAVD88, due in part to a cross-country buildup of leveling error. NGS is undertaking a series of Geoid Slope Validation Surveys in various terrain regimes (2011 in Texas, 2014 in Iowa, 2017 in Colorado) to test the accuracy of the gravimetric geoid that will be derived from the GRAV-D dataset. Periodic (updated annually) experimental geoids (Fig. 9), incorporating available GRAV-D data, are produced for user investigation and experimentation.

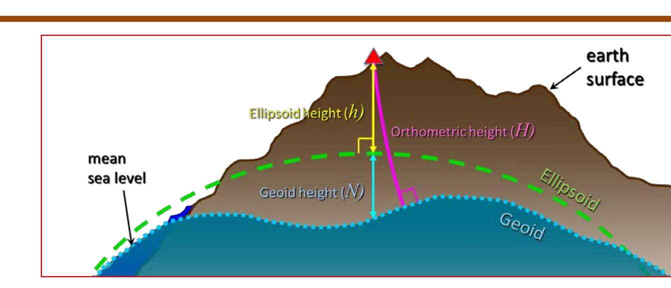


Figure 7. Schematic of vertical reference surfaces, illustrating how a GNSS-derived ellipsoid height (h) can be combined with a geoid height (N) to compute an orthometric height (H) (elevation), using H = h – N.

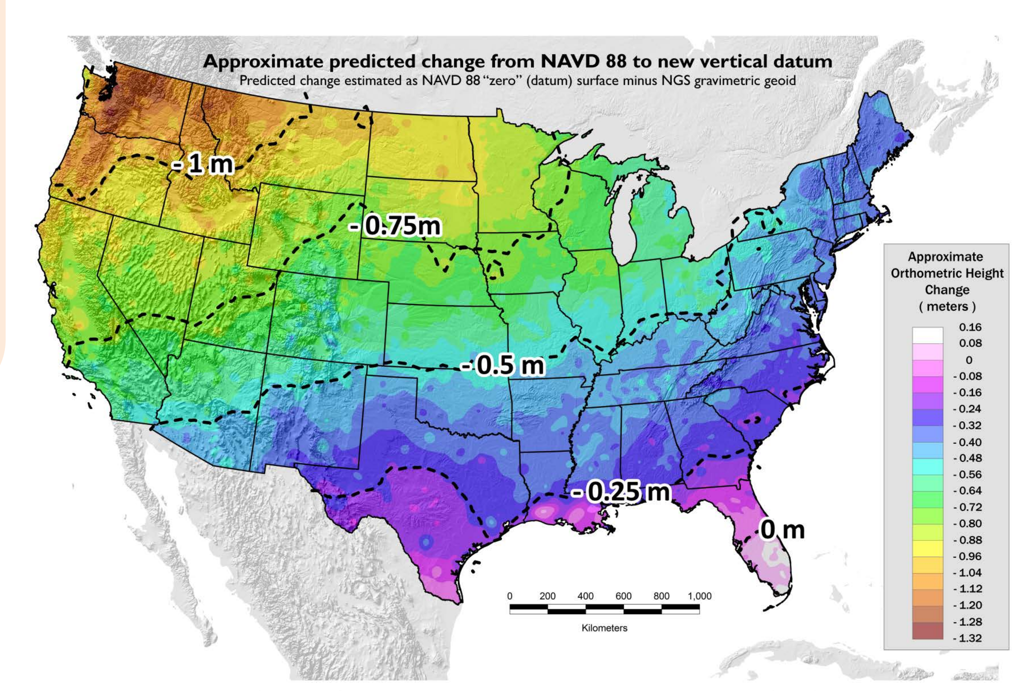


Figure 8. Plot of approximate anticipated change in orthometric height (elevation) comparing NAVD88 with the new vertical datum. Map by Brian Shaw, NGS.

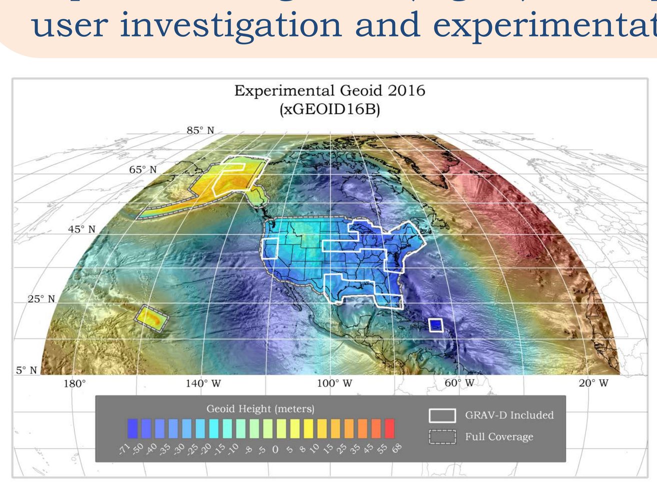
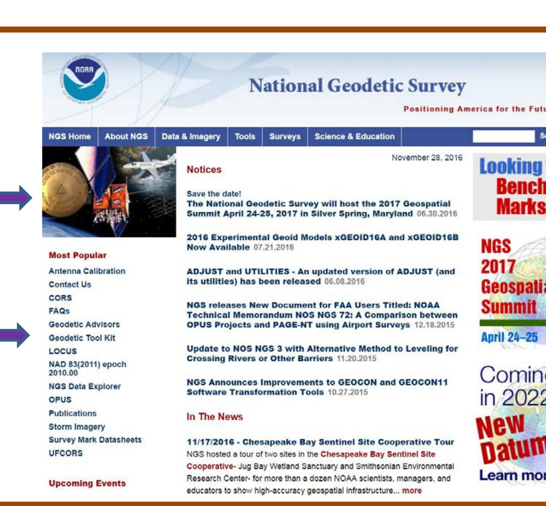


Figure 9. 2016 annual Experimental Geoid, built from GRAV-D gravity data combined with satellite gravity data, a global gravity model, terrestrial gravity data, and digital terrain data. Areas outlined in white have GRAV-D data available. NGS provides a tool for the exploration of the results of this model in areas of interest (beta.ngs.noaa.gov/GEOID/xGEOID16/).

Outreach, Education & More Information

Many details of the evolution of the new datums are still evolving. Because of the importance of the new datums to geospatial and scientific professionals in the United States, NGS is involved in substantial outreach/education with the goal of helping prepare the nation for the 2022 transition to the new datums. NGS welcomes input about the new datums from the geospatial and scientific communities. The information presented here touches on only some of the more salient features of the new datums, and more information – including tips on preparing for the new datums, tracking progress, educational videos, related projects, 2017 Geospatial Summit and much more – can be found via prominent links on the NGS homepage: http://geodesy.noaa.gov



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