Pathway to 2022: The Ongoing Modernization of the United States National Spatial Reference System

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NOAA's National Geodetic Survey

NOAA's National Geodetic Survey Mission & Vision

To define, maintain, and provide access to the National Spatial Reference System to meet our nation's economic, social, and environmental needs

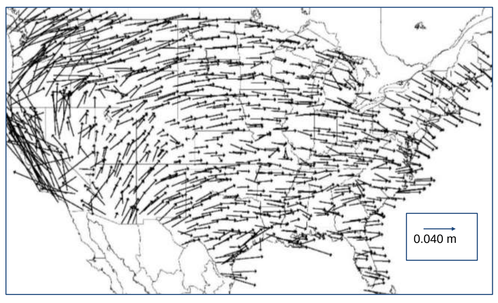
… is the mission of the United States National Oceanic and Atmospheric Administration's (NOAA) National Geodetic Survey (NGS). **The National Spatial Reference System** (NSRS) is the nation's system of latitude, longitude, height/elevation, and related geophysical and geodetic models, tools, and data, which together provide a consistent spatial framework for the broad spectrum of civilian geospatial data positioning requirements. NSRS facilitates and empowers the NGS organizational vision that …

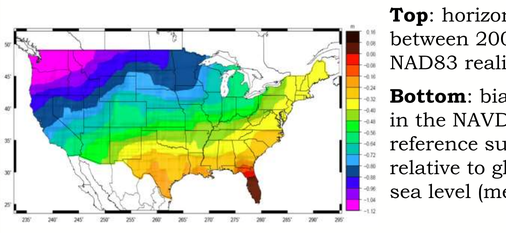
Everyone accurately knows where they are and where other things are anytime, anyplace.

To continue to accomplish the mission and further the vision of today's NGS, **the National Spatial Reference System must be modernized for tomorrow!**

Introduction

Presented here is an update, including recent naming convention and technical decisions, for the ongoing National Geodetic Survey effort to modernize the National Spatial Reference System, which will culminate in the 2022 (anticipated) replacement of all components of the current U.S. national geodetic datums and models, including the North American Datum of 1983 (NAD83) and the North American Vertical Datum of 1988 (NAVD88). This modernized three-dimensional and time-dependent national spatial framework will optimally leverage the ever-increasing capabilities of modern technologies, data, and modeling – notably the Global Navigation Satellite System (GNSS), gravity data, and geopotential/tectonic modeling – while better accommodating Earth's dynamic nature. The future NSRS will feature unprecedented accuracy and repeatability, and users will experience many efficiencies of access well beyond today's capability.





Top: horizontal shift between 2007 & 2011 NAD83 realizations

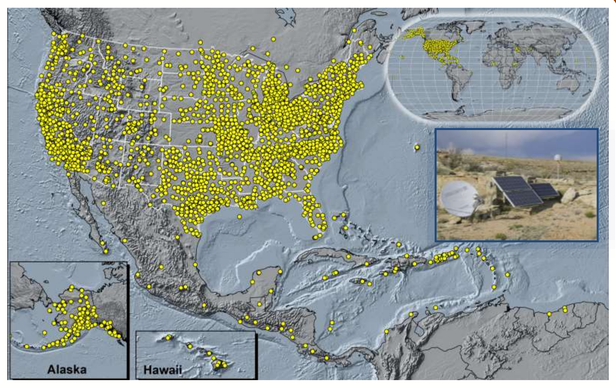
Bottom: bias and tilt in the NAVD88 zero reference surface relative to global mean sea level (meters)

Why Modernize?

Today's NSRS, while satisfying most current geospatial user requirements, is known to have shortcomings which will be addressed through the definition of new geometric reference frames and a new geopotential/vertical datum, accompanied by modern geodetic tools and models.

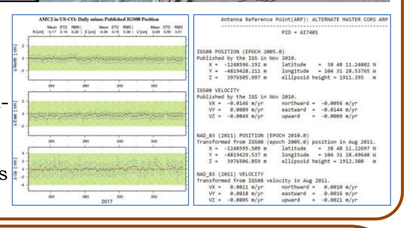
NAD83 is **non-geocentric by 2.2 m** relative to today's knowledge of the geocenter, causing it to be misaligned with the primary global GNSS-related reference frames – World Geodetic System 1984 (WGS84) and International GNSS Service 2008 (IGS08) – and related products, including GNSS satellite ephemerides and antenna models. Recent realizations of NAD83 (2007 and 2011; graphic at left) endeavored to bring into consistency the episodically occupied passive geodetic control network (80,000 stations) and the nationwide GNSS Continuously Operating Reference Station (CORS) network (2,000 stations), an effort complicated by the vastly differing nature of these passive and active networks. The CORS network (graphics at right) will define the modernized geometric reference frames and facilitate their access.

NAVD88 has a **bias (0.5 m) and tilt (1 m)** in its zero-elevation definitional surface relative to today's best determination of global mean sea level (graphic at left). It is defined primarily through a nationwide network of differentially leveled passive control stations – surveyed over decades and subject to monument movement, subsidence, degradation, and destruction – and maintenance of this passive network has become untenable.



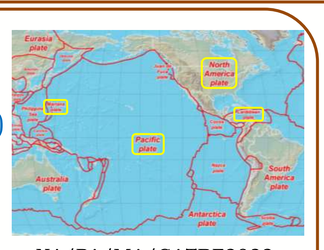
Top: CORS network and inset photo of a typical CORS site

Bottom: CORS short-term daily plots and NAD83/IGS08 coordinates/velocities for CORS AMC2



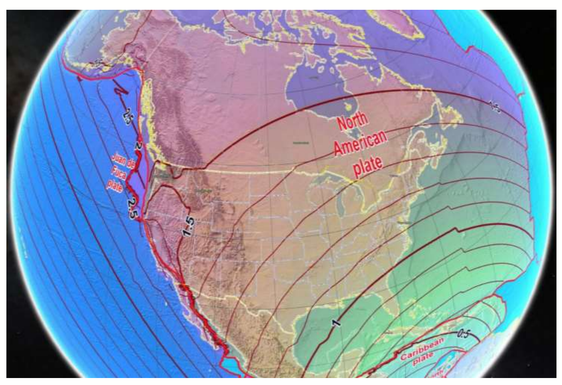
Terrestrial Reference Frames

- North American Terrestrial Reference Frame of 2022 (**NATRF2022**)
- Pacific Terrestrial Reference Frame of 2022 (**PATRF2022**)
- Mariana Terrestrial Reference Frame of 2022 (**MATRF2022**)
- Caribbean Terrestrial Reference Frame of 2022 (**CATRF2022**)

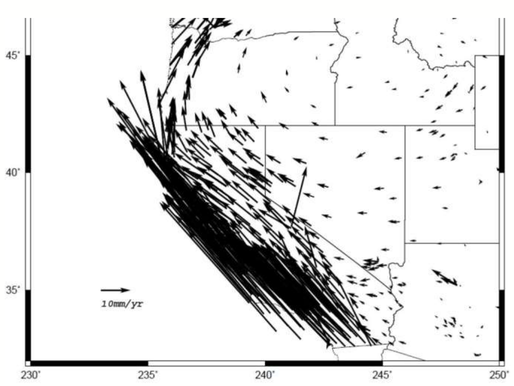


NA/PA/MA/CATRF2022 tectonic plates

The **geometric component** (latitude, longitude, ellipsoid height) of the modernized NSRS, replacing NAD83, will be realized through four **CORS-based terrestrial reference frames**, each effectively fixed and pertinent to a specific tectonic plate, as identified and indicated on the global tectonic plate map, above. Each of these frames will be identical to the 2022-current International GNSS Service (IGS) global reference frame at a specified epoch. At any other epoch, each of the four terrestrial frames will relate to the IGS global frame through the definition of an **Euler Pole** location and rotation rate, as determined through analysis of historical CORS data. All CORS horizontal velocities that deviate from rigid plate rotation (i.e. are not captured in the Euler Pole model) and vertical motions will be incorporated into a residual **intra-frame 3-D velocity model** (see below) which will allow users to compare time-dependent coordinates in any of the four terrestrial reference frames at any epoch. These models will greatly assist geospatial professionals in making optimal use of a highly accurate spatial framework while mitigating the impact of tectonic motion on accurate positioning.



Estimated change, via IGS08 epoch 2022.0 proxy, in horizontal position comparing NAD83(2011) epoch 2010.00 with NATRF2022



Non-Eulerian velocities in southwestern U.S., following removal of North America plate rotation; will be modeled by intra-frame 3-D velocity model

Geopotential / Vertical Datum

North America region for GEOID2022, DEFLEC2022, GRAV2022

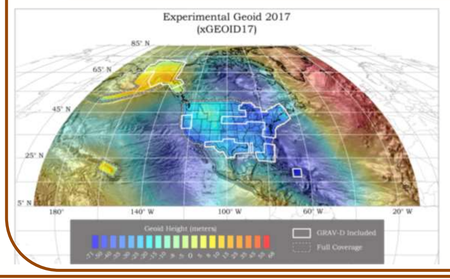
North American-Pacific Geopotential Datum of 2022 (**NAPGD2022**)

- Global model of Earth's geopotential field (**GM2022**)
- Regional gridded geoid undulation models (**GEOID2022**)
- Regional gridded deflection of the vertical models (**DEFLEC2022**)
- Regional gridded surface gravity models (**GRAV2022**)

NAPGD2022, the modernized **geopotential/vertical datum,** replacing NAVD88 and related components, will consist primarily of the four interrelated, time-dependent, IGS-based models listed above. The datum's foundational element – **GM2022** – will be a spherical (or possibly ellipsoidal) harmonic model of Earth's external gravitational potential field. **GEOID2022**, **DEFLEC2022**, and **GRAV2022** will all be gridded models built from GM2022, will require higher resolution regional information, and will cover three discrete geographic regions (greater North America [see above], Guam/ Commonwealth of Northern Mariana Islands, and American Samoa). Orthometric height (traditional elevation) will be user-determined by GNSS observations combined with **GEOID2022**, via the classic equation:

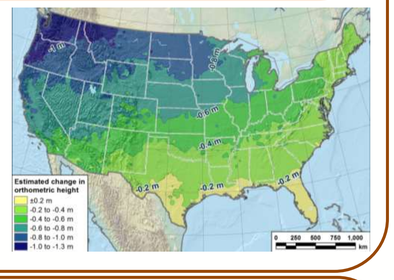
orthometric height = ellipsoid height (GNSS) – geoid height (GEOID2022)

GEOID2022 will define zero orthometric height by specifying the geopotential surface best fit to global mean sea level. Developed collaboratively with the Canadian Geodetic Survey and Mexico's Instituto Nacional de Estadistica y Geografia, GEOID2022 will provide multi-nation consistency. Development of NAPGD2022 relies on gravity datasets including satellite, terrestrial, and airborne, the latter being collected during an ambitious ongoing NGS airborne gravity data collection program – **Gravity for the Redefinition of the American Vertical Datum (GRAV-D)** – which is 65% complete (late 2017). The ability of the GRAV-D airborne gravity data to successfully support NAPGD2022 is being assessed through a series of multi-technique **Geoid Slope Validation Surveys** (Texas, 2011; Iowa, 2014; Colorado, 2017). Annual NGS **experimental geoid models**, based on current gravity data holdings, provide users with a tool to preview NAPGD2022 orthometric heights in areas of interest (see below).



Right: Estimated change - resulting from the change in datum definition - in orthometric height (elevation) comparing NAVD88 with NAPGD2022

Left: 2017 Experimental Geoid model, incorporating current gravity holdings



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❖ Thanks to Brian Shaw & Michael Dennis, both NGS, for providing many graphics

Learn More & Get Involved!

There is much more to this story than can fit on this poster, and ample opportunities exist to **learn more** about NSRS modernization and to **get involved** in the process. NGS is developing a transformation tool to relate the current/historical NSRS with the modernized paradigm. You can help build this model by contributing survey-grade GNSS observations – through NGS' **Online Positioning User Service (OPUS)** – on existing passive control stations in the NGS geodetic control database. NGS is working with the National Society of Professional Surveyors, the American Association of Geodesy, and directly with all states to determine the form of **projected coordinates systems** that each state's geospatial community elects to be developed alongside the new reference frames. Much more information on tomorrow's NSRS – including tips on **preparing** for the new reference frames/datum, related **publications**, progress tracking, educational **videos**, related **projects/research**, details on how you can get involved, and much more – can be accessed via a prominent link on the NGS homepage (see graphic at right): **https://geodesy.noaa.gov**.

2022 WILL BE HERE SOON!!