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Improving the National Spatial Reference System

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Introduction

The future of positioning is GNSS[1]. The underlying reference frames for all GNSS systems are geocentric. The International Terrestrial Reference Frame (ITRF), used for globally consistent scientific applications such as the determination of sea level change, has gotten progressively more geocentric over the last ten years, so that now the origin of the ITRF coincides with Earth's center to about 1 centimeter of accuracy. Furthermore, countries are increasingly choosing GNSS as their primary tool to access a vertical datum, minimizing their reliance upon unmonitored passive control.

In the United States, the official geometric, historically called "horizontal", datum, NAD 83[2], has a known non-geocentricity of over two meters and the official vertical datum, NAVD 88[3], is accessed through a set of passive control that is fragile, inaccurate and rapidly deteriorating. The National Geodetic Survey (NGS) is working to define and adopt a geocentric reference datum for the United States to replace NAD 83 and is working to compute an accurate geoid model which will serve as the defining surface of a new vertical datum that is accessed through GNSS technology and which replaces NAVD 88. These two changes are dependent upon one another in a variety of ways and are currently planned to occur simultaneously.

The decision to proceed with these changes was both obvious and difficult because NGS is cognizant of two important, but conflicting needs in the user community: **accuracy** and **constancy**. To fulfill its mandate to provide the geodetic reference frame for all United States geospatial activities, NGS must strive to be as scientifically accurate as possible. After much internal discussion, NGS has determined that it must address serious issues of inaccuracy in the current realizations of NAD 83 and NAVD 88. At the same time NGS recognizes that significant user resources have been invested in the current realizations of these datums.

In order to continue improving accuracy while minimizing the impact of new reference frame paradigms, NGS is working to implement this transition over the next 10 years. This will allow time for the user community to voice concerns, for NGS to address them, and to ensure that the transition will go as smoothly as possible.

For this reason, on May 11-12, 2010 NGS will convene the first in a series of Federal Geospatial Summits to address these proposed improvements to the National Spatial Reference System. The intent of these summits is to solicit user input and to provide documented solutions to address all concerns.

This white paper defines the issues as currently understood by NGS and is to serve as the catalyst for soliciting user comments, questions and concerns.

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[1] Global Navigation Satellite Systems – All constellations of positioning satellites including GPS, Galileo (Europe), GLONASS (Russia) and Compass (China)
[2] The North American Datum of 1983
[3] The North American Vertical Datum of 1988

Part 1: Replacing the North American Vertical Datum of 1988 as the official U.S. Vertical Datum

Background

Significant changes to the science and methodology of geodetic leveling occurred during the mid-20th century. A widespread multi-agency effort to collect terrestrial gravity measurements, development of new corrections to leveling and a deeper understanding of the differences between local mean sea level (LMSL) at disparate tide gages all called into question the accuracy and reliability of the National Geodetic Vertical Datum of 1929 (NGVD 29). These improvements in scientific knowledge, and the new 625,000 kilometers of leveling (including 81,500 kilometers of 1st order re-leveling) performed post-NGVD 29 were used to create the North American Vertical Datum of 1988 (NAVD 88).

NAVD 88 was a major improvement over NGVD 29, however no nationwide effort to re-adjust NAVD 88 has been made since its inception. Some localized leveling has allowed for original heights to be superseded, and in some cases (e.g. Louisiana) a number of questionable heights have been removed in favor of updated leveling and GPS-based heights. Without an active maintenance plan, current regional distortions in the network are already impacting its value and effectiveness.

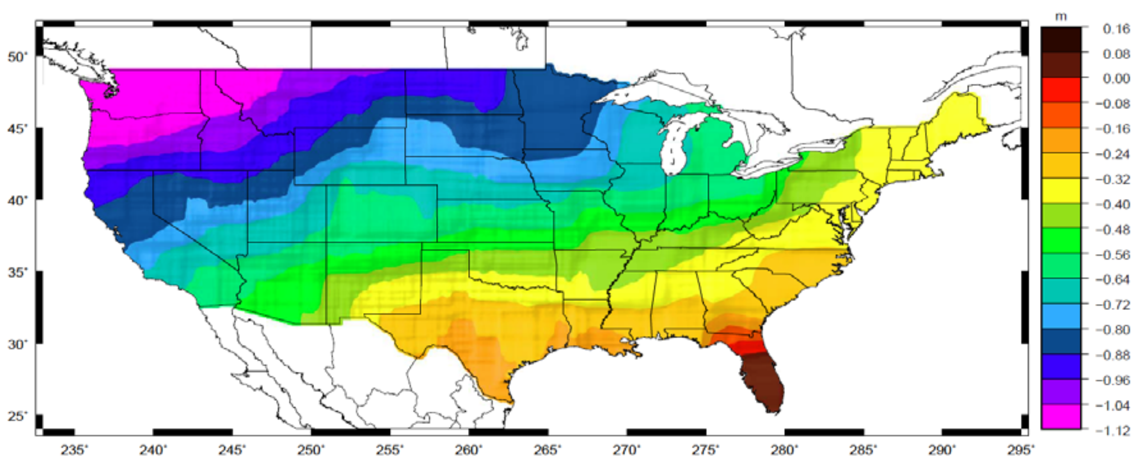
Because of known problems in the original realization of NAVD 88, and ongoing problems in the very nature of a passive-mark based system of vertical geodetic control, NGS proposed in their 10 year plan (NGS, 2008) that "a new geopotential datum…is defined and realized through the combination of GNSS technology and gravity field modeling". There are six major issues with NAVD 88 which warrant its replacement:

1) Cross-country accumulation of errors from geodetic leveling
2) Fragility and location of passive marks
3) Bias in the NAVD 88 H=0 reference surface as compared to the geoid
4) Subsidence, uplift, and other crustal motions
5) Sea level change
6) Changes to Earth's gravity field

Cross-country Accumulation of Errors from Geodetic Leveling

NAVD 88 is realized through the publication of geopotential numbers (and orthometric heights) at hundreds of thousands of passive geodetic control marks across the North American continent. These geopotential numbers were computed through an adjustment of geodetic leveling, holding a single point, Father Point/Rimouski, fixed. While this method removed the existent warping in NGVD 29 caused by holding multiple tide gages fixed, it introduced the potential for an accumulation of systematic errors across the country as leveling spread out from Father Point. As a most optimistic prediction of these errors, one can simply propagate the best estimate of 1st Order, Class II leveling (0.7 $mm/\sqrt{km}$) over the 4000 km from Father Point to Los Angeles and the predicted error accumulation would only be 4.4 cm. However, this equation only accounts for random observational errors, and fails to consider any theoretical errors, such as the formulae used to convert leveled height differences into geopotential numbers in mountainous terrain. As will be seen, it is possible that serious theoretical issues may exist. However, for the sake of simplicity, the combination of observational and theoretical errors will henceforth be simply called "leveling errors". Independent tests (Zilkoski, et al, 1992), performed immediately after NAVD 88 (using VLBI[4] and GEOID90), showed a more pessimistic estimate than 4.4 cm. In those tests, discrepancies (which must be interpreted as a combination of leveling, geoid modeling and VLBI errors) were seen in the -105 to +76 cm range at various locations around the USA. It is difficult, in such early tests, to separate how much of those discrepancies are due to leveling alone.

A significantly more reliable estimate of error accumulation from leveling alone was performed in 2004 (Wang, et al, 2004)using published NAVD 88 heights, co-located with GPS-derived ellipsoid heights and a long-wavelength geoid model, derived entirely from the GRACE[5] satellite mission. Spatial filtering of the leveling and GPS data to the wavelengths accessible from GRACE removed localized issues and allowed for a continent-wide view of these discrepancies. Because the accuracy of the GPS data and the GRACE data is in the 1-3 cm range in an absolute sense, any significant discrepancies can justifiably be identified as cross-country error in NAVD 88. The differences are shown in the figure below, and range from about 16 cm in Florida to -112 cm in the Pacific Northwest. The figure below is an update to one that first appeared in Wang, et al, 2004. The average value is non-zero due partially to the bias in the choice of the NAVD 88 H=0 constraint, to be discussed later. Note that the errors do not correlate with radial distance from Father Point, indicating the complex nature of the issue, and difficulty with expecting the standard error model of geodetic leveling to yield true error estimates cross-continent.



[4] VLBI: Very Long Baseline Interferometry – A measurement technique capable of determining geometric vectors between widely separated points, based on the observation of quasars by radioastrometry antennas at each point
[5] GRACE: Gravity Recovery and Climate Experiment

Fragility and Location of Passive Marks

From evidence submitted by users of NAVD 88, NGS has determined that thousands of bench marks are lost or displaced every year. Because the method of accessing the datum is through direct contact with a passive mark, this fragility in the vertical control network is of no small consequence. A significant portion of bench marks are located along roads and railways. This has the obvious advantage of providing ease of access and long flat stretches for leveling. But any construction project (road widening, railway removal, etc) along those corridors can result in the simultaneous removal of a huge number of bench marks. Another disadvantage of using transportation corridors to build the vertical control network is the non-homogenous geographic distribution of the NAVD 88 bench marks. Users who do not work near level lines are at a financial disadvantage relative to those who do.
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Bias in the NAVD 88 H=0 Reference Surface from the Geoid

When performing the minimally constrained adjustment which led to NAVD 88, the choice to hold the LMSL height as "fixed" at Father Point/Rimouski was made. And, while NAVD 88 ostensibly was to disseminate orthometric heights (heights above the geoid), the choice to fix NAVD 88 to LMSL at Father Point/Rimouski was not made because of a particular closeness of LMSL to the geoid at that point. Rather, the selection was made "to minimize the effects on National Mapping Products as requested by users…". That is, because National Mapping Products relative to NGVD 29 existed in paper form, choosing a new datum that aligned well with NGVD 29 eliminated significant map recompilation efforts. The final bias between the Father Point/Rimouski LMSL and the actual geoid remained something of an indeterminate quantity due to the lack of good geoid modeling at the time. Attempts to quantify this bias have been made at NGS since GEOID96. The most recent estimate of the bias in the NAVD 88 reference surface, using a GRACE-based geoid model, is approximately 50 cm. That is, the difference between a true orthometric height and an NAVD 88 height, anywhere in the continent, is, on average, about a half-meter.

Subsidence, Uplift and Other Crustal Motions

Of all the banes of passive vertical geodetic control marks, subsidence is amongst the worst. As the purpose of geodetic control is to provide an accurate starting height for surveying and mapping, the unrecorded movement of a passive mark set in a subsiding crust compromises the intention of the mark. Even worse, decisions made based on marks set in a subsiding crust may yield unintentional harm to life or property. For example, decisions about building homes in flood prone areas, or declaring roads to be high enough to serve as evacuation routes, must be based on accurate heights or the results can be devastating.

While subsidence, or its inverse, uplift, does not affect NAVD 88 everywhere in the country, it does have the greatest impact in coastal low-lying areas such as the Gulf of Mexico coast, Chesapeake Bay, and California agricultural regions. Accepting the perpetuation of known, but unmeasured errors in these NAVD 88 bench marks is possibly more damaging than not having any geodetic control at all.

Sea Level Change

It was the intent of NAVD 88 to provide orthometric heights to users, accepting that some bias in the network was unavoidable for national map consistency. And while orthometric heights have been colloquially called "heights above mean sea level", they are actually scientifically defined as heights (measured along the plumb line) above the geoid. The important distinction is that "sea level" does not exist anywhere but the sea, while the geoid is that surface of equal gravity potential energy that best fits but is not exactly the same as global mean sea level and therefore it extends globally, even under the continents. What is critical in the preceding statements is the question of how the geoid changes as sea level changes. It is well known that sea level is rising globally at a few millimeters per year, and with the internationally accepted definition of the geoid tied to global mean sea level, this change must also be taken into account. Even though NAVD 88 is tied to LMSL at Father Point/Rimouski, no attempt to update NAVD 88 based on a changing LMSL at that point has ever been made.

As NGS updates the geoid model so that it continually fits a changing sea level, users will eventually notice that even in areas where subsidence is not occurring, their orthometric heights will change. This reflects the reality that the vertical distance separating a given location and the global mean sea level is decreasing, which is information that should be properly conveyed to the public, particularly in coastal regions.

Changes to Earth's Gravity Field

Similar to the sea level issue, is the fact that Earth's masses are in a constant state of flux, which affects the gravity field and subsequently the geoid; however, luckily, very few mass changes are large enough to change the shape of the geoid in a measurable way over decadal time spans. An example of one significant exception is in the vicinity of Hudson Bay where the post-glacial rebound of the crust is linked with a related inflow of deep mantle masses below the crust. This gain in mass below that region of Canada causes a change to the geoid on the order of a few millimeters per year in the center of the region, with a decreasing magnitude of change radiating outward from there. Based on the definition of orthometric height, geoid changes should result in corresponding orthometric height changes, however, this is not accounted for in NAVD 88.

On the possibility of re-leveling NAVD 88

A variety of solutions to the problems listed above have been discussed, including the re-leveling of NAVD 88 itself. However, NGS would need to rely on contracted personnel, at a cost falling somewhere above $200M. Yet even this would only replicate NAVD 88 and all of the issues with it. Instead, NGS has chosen to embrace a paradigm shift, fully utilizing the strengths of GNSS and our own expertise with geoid modeling. The resultant plan is known as GRAV-D (Gravity for the Redefinition of the American Vertical Datum) and is expected to take about ten years and approximately $40M to complete, after which an accurate and temporally tracked geoid model will be available to serve as the vertical datum for the nation. As further evidence supporting this paradigm shift, a 2009 socio-economic study [Leveson, 2009] estimated that the value of current NOAA modernization efforts to replace NAVD 88 would be $4.8 billion over 15 years, including $2.2 billion in savings from improved floodplain management.

Part 2: Replacing the North American Datum of 1983 as the official U.S. Horizontal Datum

Background

As exemplified earlier, NGS has always been an early adopter of new and emerging technologies in mapping, charting and geodesy. In the case of horizontal datums, the use of Electronic Distance Measuring equipment in the 1950's helped NGS discover and quantify local and regional distortions in the North American Datum of 1927 (NAD 27) and ultimately led to the replacement of NAD 27 with NAD 83. As the new datum was coming into realization, modern space geodetic techniques such as VLBI, SLR[6], and GPS were introduced. Within just a few short years, NGS once again found itself in the position of acknowledging and attempting to fix the various local and regional distortions in the realization of the newly adopted datum. State-by-state GPS surveys, commonly referred to as the High Accuracy Reference Networks (HARNs), were conducted, first to improve latitude and longitude accuracy on passive control, followed by a second round for the determination of accurate ellipsoid heights, because height determination methods had improved post-HARNs. Eventually all of this data went into a massive re-adjustment, NSRS2007, with the goal of improving nationwide consistency and accuracy by removing state-to-state coordinate inaccuracies. While that readjustment was generally successful, yielding a median formal standard deviation of 1 cm in the horizontal and 2 cm in ellipsoid height, it did not resolve every problem with NAD 83 (including the non-geocentricity), and was only applicable to about 70,000 passive marks in North America.

The only space geodetic data widely available at the time of the first realization of NAD 83 were Transit Doppler observations. These observations had an expected uncertainty of about one meter. Latitudes and longitudes for the original realization of NAD 83 were geodetic (ellipsoidal) although lacking the necessary extraterrestrial measurement techniques to rigorously determine the geocenter of the Earth.

As GPS and SLR data became more available, and ultimately combined with other space geodetic techniques into creating the International Terrestrial Reference Frame of 1988 (ITRF88), knowledge of Earth's geocenter to the sub-decimeter level materialized. And when ITRF88 and NAD 83 3-dimensional coordinates were compared, it was seen that NAD 83 had a non-geocentricity of over two meters. Ultimately, an official transformation between NAD 83 and ITRF96 (a later realization of ITRF) was adopted by both the NGS and Geomatics Canada (now Geodetic Survey Division, Natural Resources Canada), defining the official origin offset between the two frames at 2.209 meters (Craymer, et al, 2000). All future transformations between new versions of ITRF and new realizations of NAD 83 would always return to this base non-geocentricity as the defining connection between the two.

A two meter non-geocentricity, which will manifest itself as latitude, longitude and ellipsoid height errors of ± 2 meters (globally), in a world where sub-meter instantaneous positioning will

[6] SLR: Satellite Laser Ranging – A measurement technique measuring the round trip time of lasers from the Earth to satellites orbiting the Earth, useful for determining both the center of mass of the Earth around which the satellites orbit as well as variations of the Earth's gravity field which perturb those satellite orbits

be in most handheld devices, will be a glaring error to general users. Specifically, this non-geocentricity in NAD 83 already manifests itself as a roadblock of improving accuracy by:

1) Causing inconsistency between national mapping products and GNSS orbits and positioning
2) Forcing a biased and tilted inconsistency in national geoid products (undulations and vertical deflections), necessitating the continued use of "hybrid" versus "gravimetric" geoid models until this is solved.
3) Causing confusion and inconsistency by mixing height systems when measuring sea level change, and
4) Causing an inconsistency between our national coordinate frame and that of other countries

In addition to the problems manifested by using a non-geocentric reference frame, two other problematic issues with NAD 83 need to be addressed. They are:

5) Inconsistency between coordinates of the Continuously Operating Reference Station (CORS) network and passive marks
6) Lack of velocities on passive control used to realize the datum

Inconsistency Between Mapping Products and GNSS

As stated earlier, the future of positioning is GNSS. That technology is changing so fast that soon stand-alone GNSS users will have access to inexpensive multi-constellation positioning devices that can achieve sub-meter accuracy. As this happens, a horizontal discrepancy in the national datum up to two meters will cause a variety of difficulties. For example, maps of roads in the USA may have NAD 83 coordinates, but personal navigation units work in WGS 84[7] (whose origin is geocentric to within a few centimeters). Personal navigation units are expected to eventually yield sub-meter accuracies and provide "in the lane" driving directions. Under such a scenario, comparing WGS 84 coordinates of the car to NAD 83 coordinates of the mapped roads will mean up to 2 meters of error that could cause incorrect lane determinations.

It is impractical to assume that the appropriate datum transformation would be coded accurately in every personal handheld positioning device to correct for this. The datum transformation between WGS 84 and NAD 83 was historically a concern only to geodesists, and is often coded incorrectly in commercial software, if it is coded at all. Even today there persists software which treats WGS 84 as equivalent to NAD 83. Rather than risk life and property to such misunderstandings, NGS feels that a geocentric datum is the best approach.

A Biased and Tilted Inconsistency in National Geoid Products

While ± 2 meter errors in horizontal coordinates are certainly worrisome for some applications, as discussed above, the ± 2 meter vertical error is much more problematic. Consider one of the

[7] World Geodetic System of 1984 – Defined and maintained by the Department of Defense, and in which frame the broadcast positions of GPS are provided

most fundamental height equations of geodesy, which converts the ellipsoid heights (h) as derived from GPS into orthometric heights (H), as used on topographic maps, through a model of geoid undulations (N):

$$H = h - N$$

Currently, in the official datums of the USA, this equation is incorrect at the level of a few meters. This is partly due to measurable systematic errors in the orthometric heights, addressed earlier, but partly due to a tilted set of systematic errors in NAD 83 ellipsoid heights. This error ranges from about 1.5 meters in Florida to 0.3 meters in the Pacific Northwest, just to use the Conterminous USA example, due to the non-geocentricity of NAD 83. In order to "close" the above equation, NGS produces a "hybrid geoid" model (N*) so that the modified equation reads:

$$[H + \text{systematic errors in NAVD 88}] = [h + \text{systematic errors in NAD 83}] - N^*$$

NGS is addressing this issue by replacing both NAD 83 and NAVD 88, so that the original equation will close using newly defined official datums for the NSRS.

<u>Confusion and Inconsistency when Measuring Sea Level Change</u>

As both a program office of NOAA, and a provider of scientific positioning services to the United States, NGS is engaged in many activities that seek to quantify sea level change, which is a global phenomenon and one that is studied best without bias from national height systems. Satellite altimeters that orbit around the center of mass of the Earth and measure sea level change in the open ocean are making measurements relative to a geocentric ellipsoid, not NAD 83. But, the official ellipsoid height system of the USA remains NAD 83, and so GPS surveys performed at tide gages in the United States, a source of local sea level change detection, would tend to use NAD 83 ellipsoid heights. This sort of inconsistency must be accounted for all the time when national and global studies are compared. The sea level community should have one set of ellipsoid heights that are consistent, globally and locally.

<u>Inconsistency between coordinate frames of U.S. and other countries</u>

NGS works closely with many countries, and on issues of national datum definition NGS has always worked with our closest neighbors. While Canada and the United States are currently in the NAD 83 system, Mexico has adopted the geocentric ITRF system for use in their country. By moving toward a geocentric reference frame, the USA and Mexico may find more consistency in cross-border geospatial work. NGS is also in active discussions with Canada about plans to move away from NAD 83, but the final decision of the Canadian government toward replacing NAD 83 is not yet clear. For the same reasons stated in this paper, many other countries have moved to a geocentric reference frame including New Zealand (NZGD2000), Australia (GDA94) and Malaysia (GDM2000).

Inconsistent Coordinates, CORS to Passive Marks

The earth is dynamic, and as a result all geodetic control is in motion and coordinates are not static. In the past this was not a problem because the measurement errors far exceeded the magnitude of the motion. So, historically, a passive mark with a "known" coordinate was the way to provide geodetic control to a surveyor or mapmaker.

Today, the proliferation of continuous GPS sites and Real Time Networks, yielding differential accuracies of a few centimeters, make relying on a long-outdated "known" coordinate on a passive mark unnecessary. Doing so can cause inconsistencies between maps and coordinates computed using active GPS control.

The most recent example of this is a re-adjustment of all available GPS data observed on passive marks in the USA. That re-adjustment, called NSRS2007, was designed to reconcile GPS vectors through a 15 year time span to a common epoch, using the Horizontal Time Dependent Positioning (HTDP) tool. Unfortunately, a variety of issues have prevented full consistency between CORS and NSRS2007. For example, no accounting of the vertical motion of passive marks was made.

There have been many proposals to address this inconsistency, including a new realization of NAD 83 where the velocities of the passive marks would be estimated, rather than solving for a coordinate set fixed in time. Alternatively, if a three dimensional crustal motion model were available, another readjustment of the passive marks could be done to gain consistency with CORS.

Both of the above approaches treat passive and active control as equally important methods of accessing the geometric reference frame. There is another alternative, which is to purposefully define the active control as the only direct access to the geometric reference frame. In this way, passive control becomes a secondary form of access, and only viable if the passive control coordinates are established through a GNSS survey using active control. The installation, surveying and maintenance of passive control would then pass on to users whose work relies on that control, where NGS would provide the tools[8] necessary to connect that passive control to the active control. In this way, passive control becomes "tied to" the NSRS, rather than "part of" the NSRS.

This is the approach which NGS outlined in their ten year plan (NGS, 2008). Because it is a new way of providing access to the NSRS, effectively removing most elements of passive control from the auspices of NGS responsibility, this new approach would best coincide with a new geometric reference frame. That way, when the new frame becomes active, coordinates in the new frame will only exist at active control. NGS would still provide a "mapping grade" conversion between NAD 83 and the new frame, much like NADCON was provided as a conversion from NAD 27 to NAD 83, but would not consider the converted coordinates on passive marks as part of the NSRS. As users perform GNSS surveys on passive control, they would be given tools to compute coordinates and velocities in the new frame, and tools for

[8] Some of these tools are already in public use, such as OPUS and OPUS-RS

sharing that information, but NGS would not endorse the use of that passive control as the primary method of accessing the NSRS.

Lack of Velocities on Passive Control Used to Realize the Datum

The NAD 83, like most geodetic control, must provide a framework for multiple users to arrive at consistent maps and other geospatial data. By having coordinates "frozen to an epoch", as was done with NSRS2007, this consistency is provided. On the other hand, coordinate changes are useful information and attempts to provide "the definitive coordinate" for a point, while ignoring its motion fails to provide users with the sort of information that would be beneficial to protecting life and property. Currently, the passive control included in the NSRS2007 adjustment have a coordinate set (latitude, longitude and ellipsoid height) but no estimated velocities, even if that mark was surveyed repeatedly over the 15 years preceding the readjustment.

NGS could re-adjust the GPS surveys in the NSRS2007 adjustment and solve for velocities, though success would be limited, considering that most points were not observed more than once over 15 years. Furthermore, NGS does not have the resources to engage in a campaign to re-observe all passive marks in a way that allows the regular computation of velocities.

A different approach, aligned with the issue of active/passive inconsistency, will instead be adopted. Specifically, NGS will compute velocities on passive marks where possible – that is, where users have submitted multiple GPS surveys over time on the same mark. In addition, NGS will develop three-dimensional models of Earth's crust which can be used to estimate velocities at particular locations, though such velocities will obviously only be useful if a passive mark is moving as the crust moves.

In order to reconcile the many needs for constancy in coordinates with the reality of a dynamic planet, a semi-dynamic reference frame will be incorporated. In such a scenario, NGS would provide coordinates of control at specific epochs, computed or modeled, and the velocities of those marks, as well as any known episodic motions, such as earthquakes or post-seismic relaxation. Users would then be able to choose whether to adopt a specific epoch for their work, and account for the motion of marks through time. NGS will provide accuracy, but users will have the option to adopt constancy.

Again, because this is an entirely new approach (i.e. estimating and/or computing of velocities on passive marks), this is best done while defining a new datum. Users will know that having velocities on passive marks means they are working in the new datum and not in NAD 83.

Summary

The National Geodetic Survey has embarked on a ten year process of removing inaccuracies in the existing datums of the United States and is seeking to engage the entire geospatial community to make the transition to new datums as seamless as possible.

Many options for addressing these inaccuracies have been proposed. Only a true paradigm shift is capable of addressing all of them. By fully embracing the benefits of GNSS as the positioning tool of today, and of the future, NGS will effectively link the replacements for NAD 83 and NAVD 88 through a geocentric reference frame and gravimetric geoid model. By tracking the dynamic nature of the Earth, and giving users tools to account for it, NGS will provide a new National Spatial Reference System that is semi-dynamic. That is, a full accounting of velocities at active control and in the geoid will be maintained at NGS, but users may choose to adopt a non-dynamic frame by adopting coordinates of choice at particular epochs. Whether users choose to work in a fully dynamic or semi-dynamic frame, NGS will provide the tools for transforming between them.

By setting these targets out ten years, this pace will include time for the user community to voice concerns and for NGS to address them. Hopefully this will ensure as smooth a transition as possible. For this reason, on May 11-12, 2010, NGS will host the first of a series of Federal Geospatial Summits to address proposed improvements to the National Spatial Reference System and to receive feedback from the user community on these proposals.

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