THE American Surveyor
A Foot In The Past... An Eye To The Future
Winter 2007

Rocky Mountain High

Texas-New Mexico Boundary
Perhaps the most incorrect of any land line

RTN-101: OnGrid
An initiative in support of RTN development

Layout Technology
Combining laser and RTK for precision staking

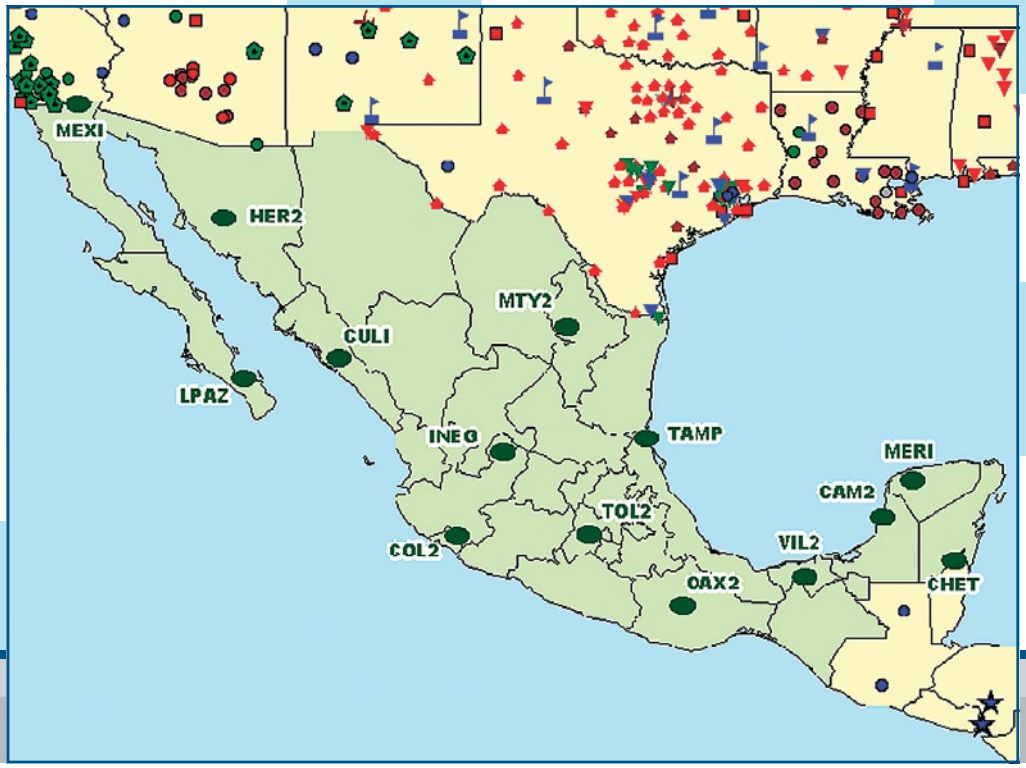

Figure 1 Active control stations and/or CORS in and around Mexico

OPUS Becomes Available in Mexico

In March 2001, NOAA's National Geodetic Survey (NGS) released a Web-based utility, called the On-line Positioning Users Service (OPUS), which has revolutionized how accurate positional coordinates are obtained. In particular, OPUS enables its users to submit a GPS data file to NGS via the Web; whereby the data will be processed using NGS computers and software to determine the positional coordinates associated with the location where the data was observed. Each data file is processed with respect to three continuously operating reference stations (CORS), and the user receives the computed coordinates via email, usually within minutes. See *http://www.ngs.noaa.gov/OPUS/* for details on the use of this utility.

Once OPUS was well established in the United States and a number of Caribbean and Central American countries, a dialogue ensued between Mexico's *Instituto Nacional de Estadística, Geografía, e Informática* (INEGI) and NGS to provide OPUS capability within the Republic of Mexico. The *Dirección General de Geografía* (DGG) is the office of INEGI responsible, among other duties, for the establishment, maintenance, and densification of the national geodetic network. DGG is also in charge of producing Mexican cartography products, primarily topographic maps at 1:50,000 and 1:20,000, which provide the backbone of the country's natural resources inventory (*http://www.inegi.gob.mx/inegi/*). Open communication between scientists at DGG and NGS resolved some minor logistic problems, and in March of 2006, OPUS was incorporated as a new Internet service to determine positions in Mexico.

Similar to the establishment of the U.S. CORS network, INEGI has developed its own *Red Geodésica Nacional Activa* (RGNA) [National Active Geodetic Network]. The RGNA has been in operation for more than 12 years, consequently,

>> By Tomás Soler, PhD, and Ing. Antonio Hernández-Navarro

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                        NGS OPUS SOLUTION REPORT
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      USER: User.Mexico@noaa.gov                DATE: March 07, 2006
RINEX FILE: ineg0620.06o                        TIME: 15:11:28 UTC


  SOFTWARE: page5  0601.10 master3.pl           START: 2006/03/03  00:00:00
 EPHEMERIS: igr13645.eph [rapid]                 STOP: 2006/03/04  00:00:00
  NAV FILE: brdc0620.06n                    OBS USED: 45959 / 47835   : 96%
  ANT NAME: TRM29659.00     NONE          # FIXED AMB:   172 /   209   : 82%
ARP HEIGHT: 0.0705                        OVERALL RMS: 0.027(m)


 REF FRAME: ITRF00(EPOCH:2004.0000)          ITRF00 (EPOCH:2006.1686)

         X:     -1260435.728(m)   0.190(m)        -1260435.752(m)   0.190(m)
         Y:     -5788547.385(m)   0.368(m)        -5788547.387(m)   0.368(m)
         Z:      2360340.145(m)   0.202(m)         2360340.131(m)   0.202(m)

       LAT:   21 51 22.15342      0.039(m)       21 51 22.15291      0.039(m)
     E LON:  257 42 56.86851      0.114(m)      257 42 56.86771      0.114(m)
     W LON:  102 17  3.13149      0.114(m)      102 17  3.13229      0.114(m)
    EL HGT:         1888.125(m)   0.445(m)              1888.126(m)   0.445(m)

                       UTM COORDINATES
                        UTM (Zone 13)
Northing (Y) [meters]     2419383.069
Easting (X)  [meters]      780685.164
Convergence  [degrees]       1.01169451
Point Scale                  1.00057359
Combined Factor              1.00054827
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Figure 2
OPUS report for users in Mexico

Mexico, along with the United States, pioneered the establishment of active CORS networks with the primary intention of creating the required infrastructure to support geodetic work and precisely define the national spatial reference systems (see **Figure 1**). As of this writing, OPUS only uses 12 of the 14 RGNA sites where GPS data is gathered continuously. The other two sites (TAMP and VIL2) will be added in the future, after some inherent technical problems are cleared.

Scientific collaboration between INEGI and NGS on geodetic matters has existed for many years. The extension of OPUS to Mexican territory is the culmination of many years of constant interaction and collaboration between scientists of both organizations.

Those familiar with OPUS in the United States should be able to use it with the same ease in Mexico. However, it is important to emphasize that the coordinates reported for locations in Mexico are referred to the newly adopted Mexican datum and not to the NAD83 (CORS96), as is the case for U.S. locations.

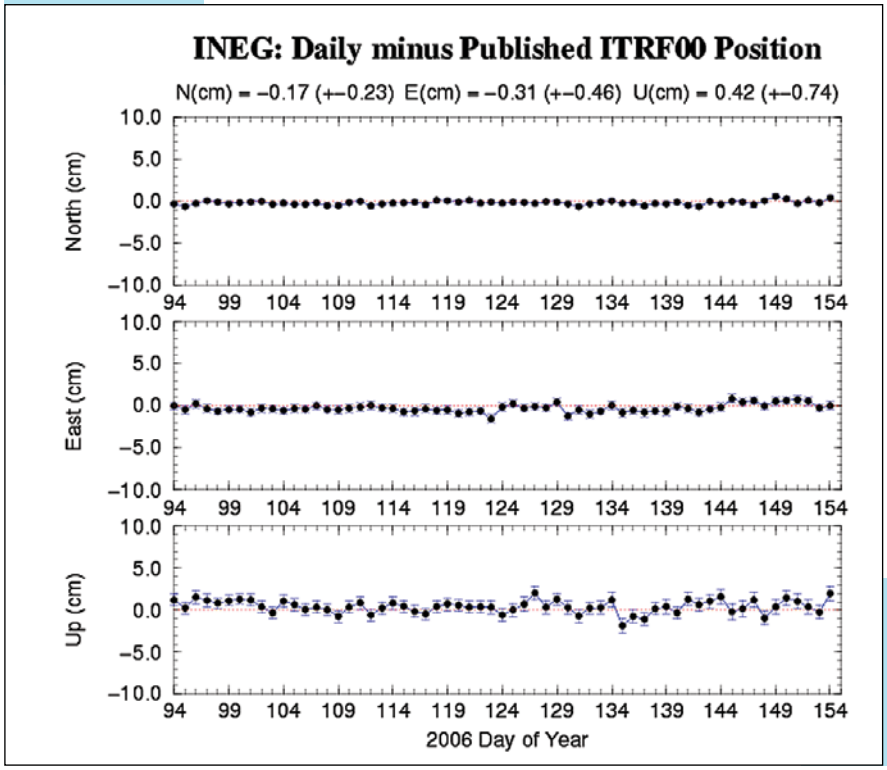

Figure 3 Variation of coordinates at the INEG site during a time period of 60 days

Mexican Datum

As in the United States, Mexico has changed its national geodetic datum on several occasions. Until 1993, all Mexican geodetic and cartographic products were referred to the North American Datum of 1927 (NAD27). Radical advances in GPS technology convinced INEGI top management to transition from the classical, mainly two dimensional methods, to more accurate, three-dimensional, GPS-based methodology. Thus, INEGI adopted a geocentric 3D coordinate frame as the basis for all its national geodetic and mapping needs. The selected frame was the International Terrestrial Reference Frame of 1992 (ITRF92), epoch 1988.0. However, recently, Mexico has further improved the definition of its geodetic reference frame by switching to ITRF2000, epoch 2004.0. The reference surface used to define the datum remains the ellipsoid of the Geodetic Reference System, as adopted by the International Association of Geodesy in December 1979, namely GRS80. The implementation of this new geocentric datum permits the integration of all Mexican geodesy, surveying, cadastral work, GIS, and mapping into a modern framework consistent with current accuracies obtainable through modern Global Navigation Satellite System (GNSS) methodologies.

OPUS Output in Mexico

For the reasons explained above, and in order to avoid unnecessary datum transformations by the user, the results provided by OPUS for locations in Mexico are referred to the Mexican datum. Therefore, besides information on the current frame (ITRF2000) and observation epoch, the information given by OPUS – when in Mexico – is composed of the coordinates in Cartesian and geodetic versions, and UTM coordinates (see **Figure 2**). Depending on the location of the observed (rover) point, OPUS could select as reference stations, CORS sites, Mexican RGNA sites, or both. The currently available option of selecting, as reference stations, any three CORS sites remains unchanged. As usual, the OPUS algorithm will select – according to the quality of the data – three reference stations; transform them to the frame ITRF2000 and observation epoch; compute a solution on this frame and epoch; and transform the results to the epoch 2004.0 using the NUVEL1A model for plate tectonics. This common effort between INEGI and NGS fulfills the desire of many private engineering and geomatic companies in Mexico and the U.S. that request the availability of OPUS in Mexico to simplify the surveying routine without losing the accuracy of the final product.

RGNA Data (Mexican National Active Geodetic Network)

People observing inside Mexico desiring to do their own data processing using RGNA sites can access the GPS data from these stations at (*http://www.ngs.noaa.gov/CORS*) and/or (*http://www.inegi.gob.mx/geo/default.asp?c=592*). NGS provides the same type of information for both CORS and RGNA sites. This includes the 60-day plots showing

the variation between the adjusted coordinates of the daily solutions of all GPS data from the adopted coordinate values. The variations are plotted along the north, east, and up (vertical) components. The effect caused by the rotation of the North American tectonic plate has been subtracted. The mean (bias) of the residuals as well as the RMS of the differences are given at the top of the figures. **Figure 3** shows the variations between adopted and determined positions for one particular site, INEG, located at INEGI headquarters in Aguascalientes. Notice that in this particular example the determined coordinates agrees well with the horizontal (red) broken line shown on the figure that represents the adopted (published) values.

Mexican Geoid

The first gravimetric Mexican geoid was computed in 1997, by NGS, with the collaboration of INEGI and was named MEXICO97. Recently, INEGI has independently determined a new gravimetric geoid for Mexico where it has incorporated all available gravimetric information including important gravimetric campaigns completed in the last few years. This Mexican geoid is referred to as the GGM05 (*http://mapserver.inegi.gob.mx/SIAG/?c=692*). This geoid should be used for all orthometric heights computation in Mexico. GPS users interested in knowing the orthometric height of any point determined by OPUS should go to the INEGI Web page mentioned previously and click the word "calcular". A window will open where, interactively, the user can introduce the latitude and longitude from the OPUS report and get the geoidal undulation (geoid height) of the point. INEGI is working to improve this geoid and, at this writing, produces geoids heights with an absolute RMS error of about 30 cm. Nevertheless, for relative determinations of orthometric heights, most of the common errors between two points will be eliminated and the results should be accurate to within a few centimeters.

Questions in Spanish about OPUS in Mexico should be addressed through the Web page: *http://www.inegi.gob.mx/lib/buzon.asp?s=geo*. Questions in English should follow the standard OPUS approach by sending an e-mail to *ngs.opus@noaa.gov*.

Dr. Tomás Soler has been a geodesist with the National Geodetic Survey (NGS), NOAA, since 1977, where he is Chief Technical Officer, Spatial Reference System Division. He is the Editor-in-Chief of "Journal of Surveying Engineering," published by the ASCE. Presently he is mainly involved with the development and analysis of CORS and OPUS results.

Ing. Antonio Hernández-Navarro has worked since 1980 at the *Instituto Nacional de Estadística, Geografía e Informática* (INEGI), Mexico, where he is Director General Adjunto de Geomática. He is a graduate from the Surveying and Geodetic Engineering Department at the *Universidad Autónoma* of Mexico (UNAM) and, currently, is completing his PhD from the University of New Brunswick, Canada. Ing. Hernández-Navarro is an expert on the definition of the Mexican Geodetic Datum and the RGNA GPS network.