The National and Cooperative CORS Systems in 2000 and Beyond

Richard A. Snay, *National Geodetic Survey, NOAA*

Proceedings of ION GPS 2000, 19-22 September 2000, Salt Lake City, UT, pp. 55-58

BIOGRAPHY

Richard A. Snay is Program Manager of the National CORS system. He received his Ph.D. in mathematics from Indiana University in 1972 and has served as a geodesist with the National Geodetic Survey since 1974. Richard also develops crustal model models that support accurate time-dependent positioning.

ABSTRACT

The National Geodetic Survey (NGS) manages the National CORS (continuously operating reference station) system that comprises a network of over 190 sites containing geodetic quality Global Positioning System (GPS) receivers. This network is currently growing at a rate of about 3 sites per month. NGS collects, processes, and distributes data from these sites in support of high-accuracy 3D positioning activities throughout the United States and its territories. In January 2000, NGS upgraded its CORS website (http://www.ngs.noaa.gov/CORS/) with a map-based interface that, among other features, enables people to easily determine whether or not a CORS site has GPS data for a specific time. NGS is also organizing the "Cooperative CORS" network that includes additional GPS base stations whose data are freely distributed by cooperating institutions via the Internet. Furthermore, NGS will soon endorse specifications for constructing a pier for mounting a permanent GPS antenna. Finally, a recent study quantifies the advantages of using hourly-updated NOAA weather models for processing GPS data.

INTRODUCTION

The National CORS (continuously operating reference stations) system comprises a network of GPS stations whose data are made publicly available for various postprocessing applications. In particular, people use CORS data to calculate GPS-derived positions with accuracies that approach a few centimeters, both horizontally and vertically. People also use CORS data for quantifying motion and for monitoring the spatial-temporal distribution of both precipitable water vapor and free electrons in the atmosphere.

The National CORS system benefits from a multi-purpose cooperative endeavor involving many government, academic, commercial, and private organizations. The system contained 191 sites as of July 2000 and is growing at a rate of about 3 sites per month. The system is also evolving in several other ways. Indeed, this article discusses several specific aspects of current CORS advancement.

IMPROVING DATA ACCESS

All CORS data are collected at a central facility in Silver Spring, MD, where these data are organized into RINEX-formatted files for public distribution. People may freely obtain these data files and related metadata either via anonymous file transfer protocol:

ftp://www.ngs.noaa.gov/cors/

or via the World Wide Web:

http://www.ngs.noaa.gov/CORS/.

In January 2000 the National Geodetic Survey (NGS) introduced a new look to the CORS web site. This new look is fondly known as CORSAGE (CORS Amiable Geographic Environment) because it enables people to access CORS data and metadata through a series of geographic maps. The CORS homepage itself features an index map in which the total area of CORS coverage has been partitioned into several color-coded regions, each usually involving a few states. By simply clicking his/her mouse on one of these regions, the user obtains a window displaying a more detailed map of that region. Each

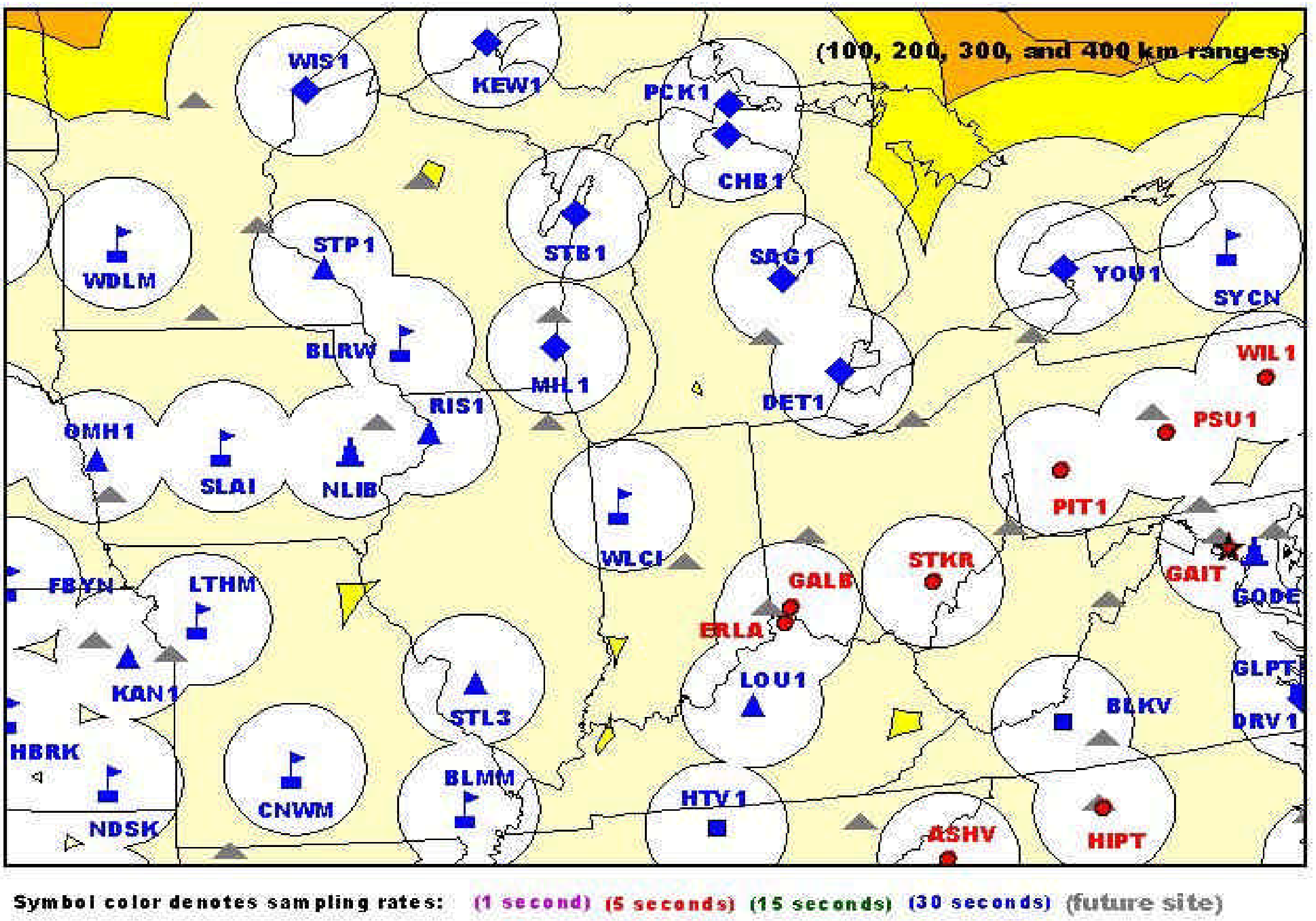

Figure 1. CORS regional coverage map for the midwest.

regional map locates the CORS sites relative to state and international boundaries and major bodies of water (Figure 1). The area of this regional map is color coded according to the distance from the nearest CORS site in increments of 100 km.

On a regional map, a user can click his/her mouse on the map symbol representing a particular CORS site to obtain a window containing a local map that pinpoints this site's location relative to nearby population centers, major roads, and other geographic features. A menu appears to the left of the local map which enables the users to view/download particular information about this site; for example, a file containing the site's position and velocity in current realizations of both the North American Datum of 1983 (NAD 83) and the International Terrestrial Reference System (ITRS). Another item on this menu enables the user to view a calendar displaying--with a 10-minute resolution--when CORS data are available for this site. Inspecting such calendars can save users from downloading and processing files that contain unwanted data gaps. Other menu items provide access to the site's GPS data and to files containing certain descriptive information about this site (type of GPS equipment, responsible institution, contact person, history of site modifications, etc.) Future plans call for adding other menu items: one for viewing photographs of the site and another for viewing time-series plots of the positions that are estimated daily using a 24-hour span of data.

ORGANIZING THE COOPERATIVE CORS NETWORK

While the number of CORS sites has been growing at a rate of about 3 sites per month, the total number of permanent GPS base stations in the United States is probably growing at least twice as fast. Because limited resources prevent NGS from including all existing GPS base stations into the National CORS system, this agency decided to organize the "Cooperative CORS" network. Organizations that maintain one or more GPS base stations may include their sites into this network if these sites meet certain specifications and if the organizations are willing to freely distribute the corresponding GPS data themselves via the Internet. NGS, for its part, will

* provide a link from the National CORS web site to the organization's web site,

Figure 2. Newly installed CORS monument at Corbin, VA with GPS antenna mounted.

* assist cooperating organizations in determining appropriate positional coordinates and velocities, and

* archive a time series of estimated positions.

Specifications for becoming a Cooperative CORS site include having a dual frequency GPS receiver/antenna capable of recording both carrier phase and code range measurements and capable of tracking at least 8 satellites simultaneously. Also, the site must be operated at least 8 hours/day, 5 days/week. Each cooperating organization, moreover, must adopt positions and velocities for their sites which are consistent with the National Spatial Reference System. Additional specifications, as well as other details about the Cooperative CORS network, may be found at

http://www.ngs.noaa.gov/CORS/Coop.

The first Cooperative CORS site came online in February 2000. By June 2000, this network had grown to 44 sites, with 40 in California and one each in Alaska, Arkansas, Colorado, and Vermont. The Cooperative CORS network is already effectively supplementing the National CORS system by providing more local access to quality GPS data in several parts of the country.

RECOMMENDING MONUMENTATION FOR A CORS SITE

A team of NGS personnel has developed recommendations for a site monumentation system for use in future CORS operations. The team recommends a step-tiered cylindrical pier that has a minimum depth of 10 ft (3.0 m) with a minimum diameter of 1.5 ft (0.46 m) below the ground, an approximate height of 5 ft (1.5 m) with an approximate diameter of 1 ft (0.3 m) above ground, and an antenna mount consisting of a traditional rotating tribrach adapter attached to a non-metallic base that is integrated into the concrete pier.

The team believes that this design is suitable for a wide range of site conditions and that it has an excellent chance for long term endurance. This type of monument provides the high level of horizontal and vertical stability required for CORS applications. The monument's shape and materials have a negligible impact on the quality of the GPS signals. The materials are readily available and affordable. The preparation of materials and the installation procedures are relatively straightforward and require only a limited amount of specialized equipment and technique. The antenna can be locked in a true north orientation and will be force-centered to a repeatable position whenever it is removed and replaced.

In November 1999, NGS installed a prototype monument of this design at its facility in Corbin, Virginia (Figure 2). The total cost for the services and materials involved in this installation was $688, excluding about 24 staff-hours of time from NGS employees. As of this writing, the team was preparing a comprehensive report on their recommendations, including explicit installation instructions. Upon completion of this report, NGS management will review the team's recommendations before issuing formal endorsement.

USING WEATHER MODELS TO IMPROVE GPS RESULTS

A team of NOAA personnel investigated a current weather model, known as MAPS (Mesoscale Analysis and Prediction System) , to determine if this model could be applied to obtain improved GPS-derived ellipsoidal heights [Marshall et al., 2000]. MAPS is the research version of the Rapid Update Cycle (RUC2) model generated by NOAA's Forecast Systems Laboratory. MAPS is generated on an hourly basis and provides coverage in the contiguous United States at a 40-km grid spacing. The team processed numerous subsets of GPS data collected over a month-long period on 23 static baselines ranging in length from 62 to 304 km. The GPS data were processed in 0.5-hr, 1-hr, 2-hr, and 4-hr session lengths.

The primary effort was to compare the precision of heights obtained when using a popular seasonal weather model [Herring, 1995] with the precision of heights obtained when using the MAPS model together with measured surface pressures. The results indicate that the current version of MAPS can lead to improvement in GPS height precision when session lengths are shorter than 2 hours. For sessions longer than 2 hours, comparably precise heights may be obtained using the less accurate seasonal model by introducing appropriate nuisance parameters into the height estimation process.

The advantage of using MAPS together with measured surface pressures as compared to using the seasonal weather model becomes more pronounced as session lengths become shorter. Results for the 0.5-hr sessions, for example, indicate that (when no nuisance parameters are estimated) MAPS with measured surface pressures yields heights with a standard error (1 sigma) of 16.9 cm, while the seasonal model yields heights with a standard error of 20.2 cm. With anticipated improvements to MAPS, this study suggests that people may eventually be able to measure heights with a standard error of about 11.0 cm using only 0.5 hours of GPS data for baselines up to 300 km in length. These improvements will involve the incorporation of GPS data from selected CORS sites into the process which generates the MAPS models.

AND BEYOND

Several other CORS-related activities are in progress at NGS. We briefly mention two such activities which we expect to impact future precise positioning applications. More detailed reports on these activities should become available in 2001.

First, a team of NGS personnel have reprocessed every third day of CORS data for the period from 1994 to 1999 to estimate a consistent set of accurate positions and velocities for the corresponding sites. This endeavor is providing new insights into site stability and coordinate accuracy. This endeavor, moreover, is supporting a rigorous study of the variation in site position which is associated with tidal loading.

Second, NGS is developing a web-based utility, to be known as OPUS (Online Processing User Service), which will quickly and automatically calculate an accurate position for a point from a user-supplied file of appropriate GPS data. According to current specifications, OPUS would require the user to supply a RINEX-formatted file containing at least a 2-hr span of carrier phase observations. OPUS would then automatically retrieve pertinent GPS data for the three nearest CORS sites for use in calculating the position associated with the user-supplied data. At the time of this writing, a prototype of OPUS was undergoing internal NGS testing.

SUMMARY

The recent introduction of the map-based CORSAGE utility to the CORS web site now enables people to easily determine which CORS sites are located in their area of interest and whether or not a CORS site has data for a specific time. The establishment of the Cooperative CORS network provides easy access to data from many additional GPS base stations. The new monumentation design offers an affordable and stable platform for mounting a CORS antenna. Finally, the MAPS weather model may be applied to obtain more accurate heights than previously possible when observing sessions are shorter than 2 hours. These and future results will enable GPS users to better determine accurate positions economically and in a timely manner when using the National CORS system.

ACKNOWLEDGMENTS

CORSAGE: Gordon Adams, Srinivas Reddy, Miranda Chin, Cindra Craig, Donald Haw, Ying Jin, J. Ross Mackay, Frank Mowry, and Neil Weston.

Cooperative CORS: Julie Prusky, Stephen Frakes, Donald Haw, Marti Ikehara, Vasanthi Kammula, and Dale Pursell.

Site Monumentation: Dennis Hoar, Roy Anderson, Miranda Chin, Michael Cline, Orland Murray, and William Stone.

Weather Study: John Marshall, Seth Gutman, Mark Schenewerk, and Richard Snay.

Multi-year solution: Mark Schenewerk, Michael Cline, William Dillinger, Mark Eckl, John Marshall, and Neil Weston.

OPUS: Neil Weston, Gerald Mader, Heeyul Han, Donald Haw, and Dennis Milbert.

Reviewers: Kathryn Milbert and Gary Young

REFERENCES

Herring, T. (1995) Personal communication. FORTRAN code developed at MIT by T. Herring and later modified and adapted by J. Ray at the National Geodetic Survey in 1995.

Marshall, J., M. Schenewerk, R. Snay, and S. Gutman (2000) The effect of the MAPS weather model on GPS-determined ellipsoidal heights. *GPS Solutions* (in press).