GPS CORS AND PRECISE ORBIT DATA FROM THE NATIONAL GEODETIC SURVEY

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ABSTRACT

The National Geodetic Survey (NGS), National Ocean Service, NOAA, is accumulating a list of Continuously Operating Reference Station (CORS) GPS data as a new product. Intended for post-processing GPS users, the CORS data and coordinates with the precise GPS orbit data provide an easy and very accurate connection to the North American Datum of 1983 and to the International Earth Rotation Service Terrestrial Reference Frame (ITRF). The CORS sites can be used as additional stations in an observing scheme or could be used to reduce the number of receivers needed to observe a project. Information is provided to explain how to obtain both the CORS and the precise orbit data. Network coverage and plans for future expansion will be discussed.

INTRODUCTION

Applications of the Global Positioning System (GPS) have exploded over the last 5 years. However, a continuing use is in the field of surveying and geodesy. Within the United States, use of GPS in surveying and geodesy was foreseen in the earliest days of GPS and for some agencies it is now the only method for determining horizontal positions. NGS terminated traditional horizontal survey operations more than ten years ago in favor of GPS.

As technology has progressed, accuracy in determining positions by NGS has increased. At the same time, the number of personnel, both in the field and in the office, has steadily diminished due to reductions in funding and the size of the Federal government. Advances in GPS hardware, software, and applications have allowed a significant reduction in the number of stations required to maintain a national control network. The first advance came with the advent of the High Accuracy Reference Networks (HARNs).

NGS "developed a set of strategic goals that include among others, (1) the establishment of a Federal Base Network (FBN); a set of high accuracy geodetic control stations at roughly 100 km spacing, (2) providing assistance, coordination, and support in establishing a Cooperative Base Network (CBN) which densifies the FBN at 25-50 km spacing ..." (Frakes, 1996)

"HARN surveys have been an ongoing high-priority activity at NGS since 1988, even before the strategic plan was fully developed. Typically, the HARN surveys have been accomplished on a state-by-state basis with NGS performing the surveying in cooperation with the lead surveying organization(s) in the state. By the end of 1996, NGS field crews and cooperating organizations will have completed HARN surveys in 44 states. The HARN surveys in the remaining six states will probably be completed in 1997." (Frakes, 1996)

NGS recognized that the acceptance of HARNs depended upon GPS users. This meant that users must recognize the value of and have easy access to the high accuracy control surveys. The first HARNs to be completed were met with caution, changing into enthusiasm when it was found how easily GPS-controlled surveys adjusted into the North American Datum of 1983 (NAD 83). There still remained a need to make high accuracy control easily available to the GPS-using public.

At the same time some agencies began computing more accurate post-fit ("precise") GPS orbits using global networks of GPS receivers operating 24-hours a day, 7-days a week. The networks were coordinated or operated by agencies such as NGS (Cooperative International GPS Network [CIGNET]) or NASA's Jet Propulsion Laboratory (FLINN network), among others. Most of the networks came together under the aegis of the International GPS Service for Geodynamics (IGS). NGS recognized the value of a similar network of stations within the United States and began working on a proposal for the CORS network.

CORS

The CORS sites from which NGS provides data are GPS reference stations operated by several Federal and local agencies which use geodetic quality, dual-frequency GPS receivers. The receivers provide code range and carrier phase data to users in support of post-processing applications. Each of the sites has been positioned accurately and is monitored on a daily basis to detect antenna movement and/or data problems. Government, academic, and private users are supported in performing after-the-fact positioning of fixed points and moving platforms. Network sites allow easy and accurate connection to the National Spatial Reference System and they also can be used as additional receivers in an observing scheme.

Coordinates for each site are computed from 24-hour data sets over a 10-15 day period and averaged for a highly accurate tie to an earth-centered, earth-fixed reference frame (Snay 1996). The reference frame being used is the latest version of the ITRF. Coordinates of sites computed by the International Earth Rotation Service (IERS) are held fixed in ITRF during the CORS site coordinate computations. Subsequently, these highly accurate coordinates are transformed into the North American Datum of 1983 (NAD 83) for use by local surveyors and engineers.

The NGS CORS network began experimental operations with one site on February 19, 1994. The number of sites increased to eight in January 1995, 17 in June 1995, 37 by mid-December 1995, and over 60 sites by early February 1996. Ultimately, the CORS network will include 100-200 stations located nationwide. NGS expects to declare the network operational by mid-1996, even though the network will continue to expand through 1998. The station distribution was in the coastal and Great Lakes areas as the U.S. Coast Guard (USCG) Differential GPS (DGPS) stations became operational. Additional stations funded by the Army Corps of Engineers (COE), Federal Aviation Administration (FAA), and other Federal agencies will increase coverage in central portions of the United States (figure 1). Gaps in area coverage will be filled in with agreements with state and local agencies operating permanently-located, high quality receivers.

The CORS GPS data are being recorded at a 30-second sampling rate and are stored in the Receiver INdependent EXchange (RINEX) format, version 2 (Gurtner 1993). Data must be retrieved via FTP on the Internet and are available for 31 days after the date of acquisition. After that period, the data are archived on CD ROMs and will be available over the Internet by special request. NGS plans to interpolate range data to a 5-second rate for users who require it. The interpolation software is currently being developed.

File Transfer Protocol

To retrieve CORS data files one must use the Internet and the File Transfer Protocol (FTP). FTP copies files over a connection between the local "client" or user's computer and a remote "server" computer. FTP runs on the user's computer. The user's computer system must have access to the Internet and support the File Transfer Protocol. Some useful ftp commands are given below.

ascii	set ascii transfer type
binary	set binary transfer type
bye	terminate ftp session and exit
cd	change remote working directory
dir	list contents of remote directory
get	retrieve one file
help	print local help information
mget	retrieve multiple files
mput	send multiple files
prompt	force prompting on multiple commands
put	send one file
quit	terminate ftp session and exit

Actual commands may vary among operating systems.

To Access CORS Data Type the "ftp" command followed by the INTERNET address:

```
ftp proton.ngs.noaa.gov (or 140.90.111.134)
Login: anonymous
Password: your complete e-mail address
```

The user will arrive at the ftp command level indicated by the prompt "ftp>". If you experience problems, type "help" to print local help information or review the section FILE TRANSFER PROTOCOL for help with additional commands. A note of caution: PROTON is a computer with a UNIX operating system. UNIX is case sensitive, so ensure that commands are entered as displayed. Almost all UNIX commands are lower case, but files or directories may contain upper and/or lower case letters. When changing directories the special character "/" must be used rather than "\" as in DOS. UNIX allows file names longer than eight characters and multiple extensions longer than eight characters. So, when transferring files, the user must ensure that the file names are compatible with his/her operating system.

All CORS related directories and files are located in the directory "cors" and can be accessed by typing:

```
cd cors.
```

The following sub-directories contain additional files and information.

coord	files with NAD 83 and ITRF coordinates for the CORS sites
itrf	Files with information about the ITRF
rinex	RINEX formatted data files
station_log	Files with station information, antenna specifications, and site contacts
utilities	Programs for manipulating the RINEX files

RINEX File Naming Convention

The RINEX file naming convention is as follows:

{SSSS}{DDD}{H}.{YY}{T} where SSSS is the four character site identifier,
DDD is the day of year,
H is a letter which matches an hour-long UTC time block,
YY is the year, and
T is the file type.

Hourly UTC time block identifier (H)

Hour:	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
H:	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p
Hour:	16	17	18	19	20	21	22	23								
H:	q	r	s	t	u	v	w	x								

File type	Ending (T)
Meteorological	m
Observation	o
Navigation	n
Summary	sum or s

For example: gait060b.96o or mia1073q.96n

Access Via WWW

NGS has developed a home page on the Internet World Wide Web (WWW) for online access to its products, services, and program activities. The CORS products and data are available through NGS' home page which is accessible through either NOAA's home page or by typing in the URL (Uniform Resource Locator):

http://www.ngs.noaa.gov

when using a browsing tool such as Mosaic or Netscape for DOS or UNIX computers.

File Format

Since October 7, 1995 (day 280), RINEX files have been stored on NGS computers in the GZIP compressed format. Prior to that date the files were stored in UNIX compressed format. GZIP compressed files have the extension ".gz" appended. (UNIX has ".Z" appended.) One may retrieve the compressed files by using the "get" or "mget" commands and the complete file name, including file name extensions. MGET allows the use of wildcard characters. Alternatively, the file may be uncompressed before retrieving it (depending upon the Internet service) by using the "get" command followed by the filename without the ".gz" (or ".Z") extension. It is important to note that if the file is transferred in compressed mode one must set the transfer mode to "binary". Executable files (programs) must also be transferred in "binary" mode. Uncompressed RINEX files and text files should be transferred from UNIX to DOS in "ascii" mode.

Utilities

Several DOS based utility programs, with explanatory text files, are available to manage the RINEX data files. Versions exist for

other platforms such as Silicon Graphics (sgi), Sun Microsystems (sun), and Hewlett Packard (hp).

cato.exe	Utility to join two or more RINEX observation files. Records the type and order of the data field in the first file. This order is used in all subsequent files.
gzip386.exe	Utility program to compress or uncompress files (.gz, .Z).
join24pc.exe	Utility program to join two or more hourly RINEX observation or navigation files.
decimate.exe	Utility program to reduce the epoch data rate to a user specified rate.

NOTE: Program DECIMATE, used to reduce the size of the observation and navigation files, will only remove epochs which are a multiple of the sampling rate. Program JOIN24 will not join hourly files after 2400 UTC.

Electronic Messages (e-mail) If a user wishes to be added to the NGS CORS e-mail list, he/she must notify Don Haw (don@ngs.noaa.gov). A weekly newsletter will be sent via e-mail with information about CORS status and availability.

Additional Information or Requests For additional information about the NGS CORS, please contact the appropriate person below.

Administration:	William E. Strange bstrange@ngs.noaa.gov (301) 713-3222
	Paul R. Spofford pauls@ngs.noaa.gov (301) 713-3205
Information/ special requests	Donald Haw don@ngs.noaa.gov (301) 713-3208
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Mailing Address

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PRECISE EPHEMERIS DATA

The National Geodetic Survey (NGS), NOAA is a participant in the Civil GPS Service Interface Committee (CGSIC). In April 1990, NOAA's NGS agreed to be responsible for providing post-fit GPS ephemerides to the civil community. NGS began its orbit computation process, before the CGSIC agreement, with the development of program PAGE (Program for Adjusting GPS Ephemerides) and the assignment of personnel to test the software using tracking data collected by the Cooperative International GPS Network (CIGNET).

PAGE, v1.0, used dual-frequency pseudorange data from six tracking sites in North America and Europe over 9-day periods to compute 7-day orbits. The orbits were estimated to be accurate to about 15 meters. When Selective Availability was implemented by the Department of Defense in March 1990 NGS decided to rewrite the PAGE software to double difference carrier phase data. The technique largely removes clock errors, as well as the effects of SA. The resulting software, PAGE2, was introduced in April 1991 and improved orbit accuracy to 1-3 meters. In February 1994, PAGE3 was released and brought NGS in conformance with IGS computational methods. Orbital accuracies improved to 20-25 centimeters by using common models and global tracking sites, and Earth Orientation Parameters were produced. In August 1995, NGS released PAGE4, which had an improved tropospheric model. By fixing the coordinates of a standard group of fiducial sites orbit accuracy improved to 9-15 centimeters.

The first ephemeris released to the public, GPS week 602 (July 21-27, 1991), was sent to the Department of Transportation's Global Positioning System Information Center, later the Navigation Information Service (NIS), bulletin board on September 25, 1991. NIS is operated by the U.S. Coast Guard Navigation Center and is based in Alexandria, Virginia (USCG 1995). NGS ephemerides were released in 7-day data sets with a 4-hour overlap added to both the start and end of the week. On February 26, 1994, the orbit format was converted from 7-day to 24-hour data sets, with a 3-month changeover period. Ephemeris distribution through NIS has continued to the present.

In 1991, all six sites were fixed to known coordinates in a Very Long Base Line (VLBI) defined reference frame. NGS is now an active Analysis Center in the IGS. Current computations now regularly include data from more than 53 globally distributed sites. The coordinates of the 13 to 15 fundamental sites are held fixed in the most current version of ITRF adopted by IGS.

Access to Orbits

NOAA post-fit GPS ephemeris data, commonly referred to as precise orbits, are distributed using several methods. The orbits are provided in formats EF18 (DOS binary) and/or SP3 (ASCII) (Remondi 1989, Remondi 1991), depending upon the distribution point.

Daily orbits, begun February 26, 1994, are normally computed and distributed within 2 to 6 days after the day of observation. Each orbit covers a 24-hour period with a 15-minute epoch. Satellite clock offsets, extracted from GPS broadcast messages, are added to each epoch of the orbit data, however, the clock data are not corrected for DoD introduced errors. An informational summary file is generated to document the computation and to provide relevant information about the observed satellites, such as maneuvers and health status.

INTERNET Access The 24-hour orbit in SP3 format and the summary file are transferred by the Internet to several locations for users. First, to the Crustal Dynamics Data Information Service (CDDIS), Goddard Space Flight Center, NASA, Greenbelt, MD. CDDIS is a Global Data Center for IGS. To request access as a user, contact Ms. Carey Noll, 301-286-9283 or noll@cddis.gsfc.nasa.gov.

The file naming convention is as follows:

ngsnnnnx.aaa, where ngs = National Geodetic Survey
nnnn = GPS Week Number, e.g., 0745
x = day of week, Sunday = 0, ...,
Saturday = 6, weeklong = 7
aaa = file type, SP3, sum, erp
(erp = earth rotation
parameters)

A second location is the Geosciences Laboratory, NGS, NOAA. The orbits are available via an anonymous FTP logon to the host computer GRACIE (ftp gracie.grdl.noaa.gov, in the directory /dist/cignet/Ngsorbits). The files are in UNIX compressed format (signified by a ".Z" appended to the file name). The file naming convention is as above.

A third location is the Internet World Wide Web (WWW). The Uniform Resource Locator address for NGS' home page is:

http://www.ngs.noaa.gov

Click on "NGS Products and Services" and then "GPS Orbital Data". A WWW location at the Coast Guard Navigation Center is:
http://www.navcen.uscg.mil

Click on "Global Positioning System", "Latest Precise GPS Ephemeris Data and Information", and then the data category desired. Note that the file naming convention and epoch interval

is the same as listed below under Bulletin Board Access. SP3 and EF18 (DOS binary) format data are available. The home pages are accessible by using a WWW software browsing tool.

Bulletin Board Access The 24-hour orbit is modified for the general public to reduce telephone charges. A DOS binary version (EF18) of the ASCII (SP3) orbit is created, 4-hour overlaps are added, and the epoch interval is converted from 15 to 40 minutes. Finally, a text section is added to the summary (SUM) file.

The modified files (SP3, EF18, SUM) are then transmitted to the NIS bulletin board. The bulletin board telephone number is 703-313-5910 (N-8-1-full duplex). Modem baud rates are 28,800 or 14,400. The file naming convention for these files is:

NGYYMMDD.AAA, where NG = National Geodetic Survey
YY = year, e.g., 94
MM = month, i.e., JA, FE, MR, AP, MY, JN, JL, AU, SE, OC, NO, DE
DD = day of month, 01-31
AAA = file type, SP3, E18, or SUM

Utility programs to modify or to join successive days together are available on the bulletin board (menus MAIN, GPS, PRECISE) in file UTILITY.EXE, a self extracting zip file.

NGS operates its own bulletin board from which the precise orbits can be retrieved. The file format and naming convention is the same as those found for the ftp location gracie.grdl.noaa.gov. The telephone number is 301-713-4181 or 4182. (N-8-1-full duplex) The orbits have 15 minute epochs and are in UNIX compressed format. The modem baud rate is 14,400.

Diskette Distribution The final distribution point is the Information Services Branch, Geodetic Services Division, NGS. The orbits distributed are the seven daily files of each GPS Week concatenated together with 4-hour overlaps at each end of the week. The orbit files have a 40-minute epoch interval and are in the SP3 and EF18 (DOS binary) formats. In addition, the daily summary files are concatenated and supplemented with an explanatory text segment. The file naming convention is:

SP3ASCII.nnn
EF18BIN.nnn
WEEKnnn.SUM where nnn = GPS Week Number, e.g., 745.

NOAA weekly orbits are available for a nominal fee beginning with GPS Week 602 (July 1991) through the present. The orbits will be delivered on high density diskettes and include utility programs.

Users may order by telephone (301-713-3242), by FAX (301-713-4172), or by mail:

NOAA, National Geodetic Survey
N/NGS12, SSMC3
1315 East-West Highway
Silver Spring, Maryland 20910-3282.

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