IGS

SESSION 4

DEMONSTRATIONS AND POSTER PAPERS

IGS

CURRENT NETWORK PERFORMANCE

Westford GPS to VLBI Vertical Tie and the TRF Accuracy

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The difference between the heights of the VLBI and GPS antennas at Westford as found in ITRF96 differs from the optical survey value by approximately 3 cm. The height of the GPS antenna is, however, a function of elevation cutoff with a sensitivity of approximately -3 mm/°. In Figure 1 the height difference as calculated from ITRF96 and as measured by conventional optical measurements is compared to the average of estimates by GPS from ten days of data for analyses with minimum elevations from 5° to 30°. The GPS component of the height difference was measured from the WES2 Dorne-Margolin choke-ring antenna to an identical antenna mounted on a tripod over a mark next to the VLBI antenna. (Previous GPS measurements were made using different antenna types for the reference marks.)

A sample of other Dorne-Margolin choke-ring antennas of the IGS network (Figure 2) shows sensitivities measured on one day that range from very small change in height with minimum elevation change to as much as –10 mm/° for CAS1. **These height differences will not be reduced by any common elevation-dependent phase center correction.** The data for a DMCR antenna mounted on a tripod over a grassy field, the best characteristics yet observed, are shown in Figure 3.

One elevation-dependent error in heights that can be corrected is that due to the addition of a radome. The effect of the Ashtech radome is shown in Figure 4.

Until the elevation dependent phase error can be measured *in situ* the variations in figures 1, 2, and 3 are representative of the uncertainty in absolute heights of the current GPS antennas. As a consequence the scale of the Terrestrial Reference Frame cannot be determined by GPS to better than several parts per billion, and the heights of individual sites are uncertain at the several centimeter level.

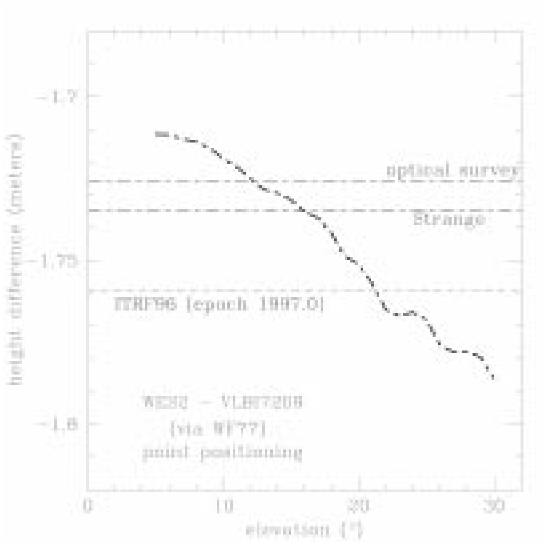


Figure 1. VLBI to GPS height difference at Westford.

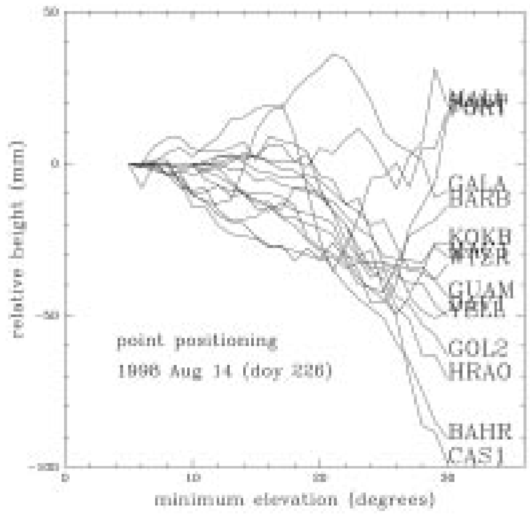


Figure 2. Height as a function of minimum elevation for DMCR antennas of the IGS global network

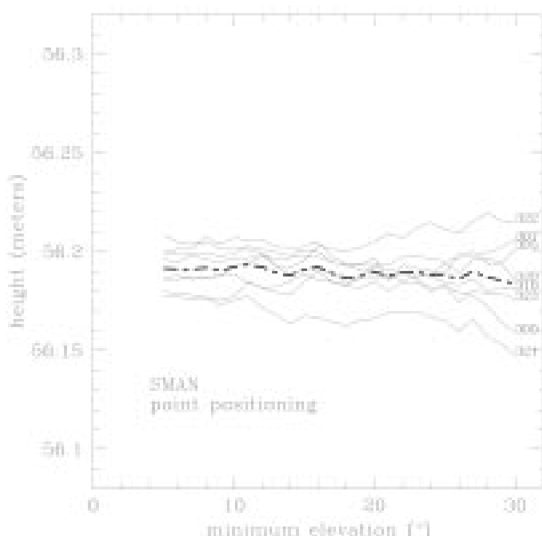


Figure 3. The height dependence for a DMCR antenna mounted on a tripod in a grassy field.

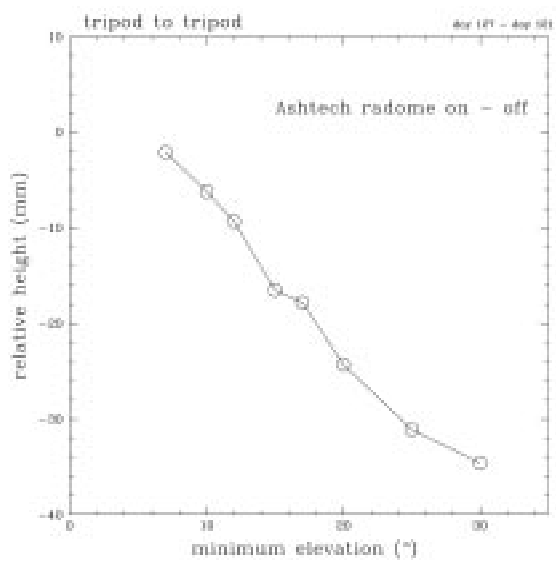


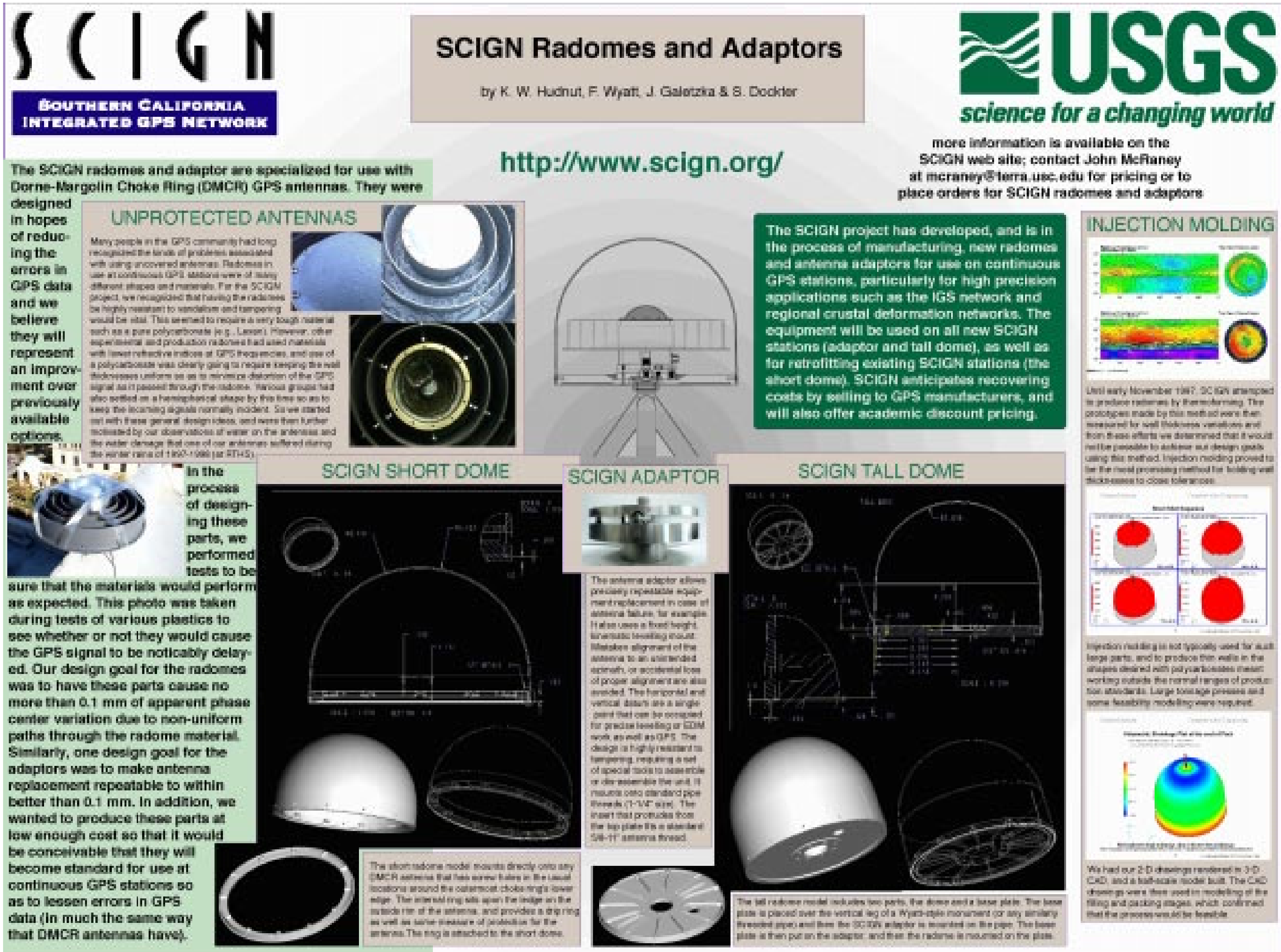
Figure 4. The height error due to Ashtech radome for the DMCR antenna.

Recommendations:

1. Use only one type of antenna for global solutions.
2. Evaluate the elevation dependence for all antennas of the GGN for ~10 days twice per year (and certainly after any change of antenna or receiver) and archive. When looking for changes over decades, such information may be useful to determine which results are most reliable.
3. Use the observed elevation sensitivities to determine what constitutes a good environment to produce low sensitivity. (Is the low sensitivity for some sites due to reduced range of observed elevations at high latitudes?)
4. Exclude those antennas with the most extreme sensitivity to minimum elevation until the sensitivity can be reduced.
5. Measure (for at least 10 days) the position of the permanent antennas relative to a tripod-mounted DMCR over a nearby reference mark, noting the elevation sensitivity of both. Compare with a conventional measurement of the position difference. If the reference has low sensitivity (Figure 3), correct the phase center offset to give the conventional position difference. Repeat when any change is made at the site.

IGS

PHYSICAL SITE SPECIFICATIONS


SCIGN
Southern California Integrated GPS Network
SCIGN Radomes and Adaptors
by K. W. Hudnut, F. Wyatt, J. Galetzka & S. Dockter
USGS
science for a changing world
http://www.scign.org/
more information is available on the SCIGN web site; contact John McRaney at mcraney@terra.usc.edu for pricing or to place orders for SCIGN radomes and adaptors
The SCIGN radomes and adaptor are specialized for use with Dorne-Margolin Choke Ring (DMCR) GPS antennas. They were designed in hopes of reducing the errors in GPS data and we believe they will represent an improvement over previously available options.
UNPROTECTED ANTENNAS
In the process of designing these parts, we performed tests to be sure that the materials would perform as expected. This photo was taken during tests of various plastics to see whether or not they would cause the GPS signal to be noticably delayed. Our design goal for the radomes was to have these parts cause no more than 0.1 mm of apparent phase center variation due to non-uniform paths through the radome material. Similarly, one design goal for the adaptors was to make antenna replacement repeatable to within better than 0.1 mm. In addition, we wanted to produce these parts at low enough cost so that it would be conceivable that they will become standard for use at continuous GPS stations so as to lessen errors in GPS data (in much the same way that DMCR antennas have).
The SCIGN project has developed, and is in the process of manufacturing, new radomes and antenna adaptors for use on continuous GPS stations, particularly for high precision applications such as the IGS network and regional crustal deformation networks. The equipment will be used on all new SCIGN stations (adaptor and tall dome), as well as for retrofitting existing SCIGN stations (the short dome). SCIGN anticipates recovering costs by selling to GPS manufacturers, and will also offer academic discount pricing.
INJECTION MOLDING
SCIGN SHORT DOME
SCIGN ADAPTOR
SCIGN TALL DOME

IGS Stations at Thule, Greenland

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Introduction

The IGS station THU1 at Thule Airbase in Greenland was established May 1995 in a coorperation between JPL and KMS. In spring 1998 authorities at Thule Airbase announced that the housing facilities for THU1 are scheduled for demolition in near future. Therefore a new site was selected and housing, monument and infrastructure facilities established during spring and summer 1998.

The new station THU2 was installed and set in operation October 26,1998. THU1 and THU2 will be operated in parallel as long as the facilities for THU1 exist.

The Existing THU1

The antenna of the THU1 station is mounted on a platform attached to the roof of a building, which is founded on a sedimentary layer that is permanent frozen in 3 ft. depth.
Instrumentation is a TurboRogue SNR12-RM with a Dorne Margolin T antenna in a custom-made plexiglass radome.

THU1 sample data at 30 sec. interval in hourly files.

The New THU2

The antenna is mounted on a concrete pillar built on solid bedrock.

Instrumentation is a Ashtech Z18 GPS/Glonass receiver with a Dorne Margolin Ashtech antenna in a plexiglass hemisphere radome (Swedish type). The station currently supports the IGEX campaign.

THU2 sample data at 30 sec. interval in 24 hour files. Rinexfiles are sent in Hatanaka compressed format to the regional datacentre at BKG.

Dataflow

Data is sent via a dial-up Internet connection to KMS in Copenhagen. Statens Kartverk in Norway is operational datacenter and is responsible for delivery of data from THU1 to BKG who distributes to the global centers.

Additionally JPL has access to hourly files from THU1 directly at KMS in Copenhagen.

Future Plans

THU2 will be equipped with meteorological sensors and external clock. Furthermore establishment of ocean tide gauge station at Thule has been planned.

IGS

DATA CENTER PROCESSES

SCIGN Operations Center at the USGS

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The GPS group at USGS-Pasadena is responsible for carrying out two primary functions within the framework of the Southern California Integrated GPS Network. The first of those functions is the management of the selection, installation, download and maintenance of 200 of the sites that are being installed. The second is the analysis of data from the array in near-real time to provide rapid estimation of coseismic displacements in southern California.

To fulfill our first responsibility, the Field Operations group (John Galetzka, Aris Aspiotes and Shannon Van Wyk) has been working with the project contractor to oversee and assist in the installation of 200 continuously operating GPS stations. In the first 18 months of existence, this group (with the valuable assistance of SIO's Paul Jamason and experienced Southern California survey professionals) performed the vast majority of potential-site reconnaissance. This led to the identification of nearly 200 new station locations that meet the stringent SCIGN site-selection criteria. Network Coordinator John Galetzka took primary responsibility for liaison with responsible authorities at these sites. Due to their efforts and with the guidance of USGS geophysicist Nancy King, permits have presently been attained for more than 100 new sites.

During the early phase of the contract, USGS personnel helped to develop the SCIGN Statement of Work on which the array is implemented, and they still serve to clarify technical questions for the SCIGN installation contractor. Shannon Van Wyk continues to work with the Ashtech group of Magellan, Inc. to manage the receipt, testing and quality control of the 250 new and replacement Z-12 receivers and choke-ring antennas destined for network duty. USGS personnel, particularly electronics technician Aris Aspiotes, developed and tested the network's AC and backup power supply system as well as the solar power configuration destined for remote environments such as the San Gabriel Mountains. Field Ops has tested a variety of modem and RF communications techniques for implementation into the array, including the feasibility of Freewave* and Metricom* radio systems within the difficult RFI of the LA Basin. Both of these systems, and others, have been implemented in the SCIGN data communications system. Presently, Field Ops is working with fellow USGS Seismic Network (TriNet) personnel on the incorporation of analog and digital microwave into SCIGN's real-time network communications. When necessary, the entire USGS group takes part in field operations, such as the replacement of TurboRogue receivers by Ashtech Z-12s at 8 SCIGN stations in the first week of January 1999.

To track the development of the SCIGN, Nancy King, Shannon Van Wyk and former USGS employee Marin Clark developed an ArcView* GIS database system. This system reflects the status of sites from the time of initial, "regional" proposal by the SCIGN "Dots" Committee, through regional reconnaissance, site selection, official contact, permitting, installation and final acceptance as performing sites. Work is now under way to extend the GIS database for the distribution of coseismic station displacements to state and federal emergency services and southern California utility and infrastructure maintainers.

In spring 1997, USGS-Pasadena was managing and downloading approximately 10 continuously operating GPS stations. As of February 1999, data from 54 of 74 SCIGN stations are being downloaded by the USGS download center. To handle the burden associated with the 20-fold increase in continuous station responsibilities, Jeff Behr and SIO's Chris Roelle developed a new software package to manage continuous GPS data, the Extendable GPS Array Data System (EGADS). This package involved the port of Ashtech's 16-bit REMOTE, HOSE and ASHTORIN software to a combined 32-bit Windows application, ASHCAN (Ashtech Communications and Networking). This new console application provides the communications and Z-12 receiver interface capability for EGADS. The Perl scripts of the EGADS system provide a cross-platform (Unix and Windows NT) umbrella that integrates station-specific, download-computer-specific and communications-device-specific information for the balanced, distributed management of remote GPS station data. This software is freely available to the greater GPS research community as a service of SCIGN. For more information, please browse *http://www-socal.wr.usgs.gov/scign/EGADS*.

To prepare for the possibility of a damaging earthquake, Jeff Behr developed automated systems that interface with the GAMIT/GLOBK analysis software to perform daily and/or sub-daily GPS solutions. Presently, this system processes all available site data beginning 8 hours after the end of the UTC day, providing daily estimates of north, east and vertical station displacements from a running least square fit to the station position time series. Results are typically available, posted to the USGS-SCIGN Analysis web page (*http://www-socal.wr.usgs.gov/scign/Analysis*), at approximately 14:00 UTC following the day of record. The system, developed for the USGS earthquake response capability, employs IGS predicted orbits to allow the rapid determination of coseismic station displacements. It has proven to be a reasonably precise system (hrms of ~6-10 mm) and observations of short-term horizontal position scatter have given early warning of developing problems with station equipment.

All of these tasks are performed under the guidance of the group's director, Dr. Ken Hudnut (SCIGN Executive Committee), assisted by Dr. Nancy King (SCIGN Board). In addition to these activities, the group has been responsible for other investigations that extend the application and accuracy of continuous GPS as well as the expertise of the USGS group. Hudnut and Galetzka, working in concert with SIO's Frank Wyatt and Stephen Dockter, developed the SCIGN radome for choke ring antennas at continuous GPS sites. Hudnut, Behr and Aspiotes have been evaluating RTK GPS systems for possible inclusion into SCIGN to aid in the estimation of earthquake deformation. Hudnut, Behr and King have investigated the use of continuous GPS in the field of structural deformation monitoring. For more information on these and other activities at USGS-SCIGN, please contact Dr. Ken Hudnut at (626) 583-7232, email *hudnut@gps.caltech.edu*, or please visit the USGS-SCIGN website at *http://www-socal.wr.usgs.gov/scign*.

* This report is preliminary and has not been reviewed for conformity with U. S. Geological Survey editorial standards. Any use of trade, product or firm names is for descriptive purposes only and does not imply endorsement by the U. S. Government

BKG Regional IGS Data Center

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Introduction

The Bundesamt fuer Kartographie und Geodaesie (BKG) acts as Regional IGS Data Center for Europe since the beginning of the IGS in 1992. Observation data of European GPS permanent stations and also stations outside of Europe, but operated by an European institution, are transferred to BKG on daily basis. During the last years new permanent operating observation networks were established and submit data to BKG. These are observations from the German permanent GPS network and the International GLONASS Experiment (IGEX). Also hourly data files are submitted to BKG by several stations for test purpose. The data form different observation networks have to be stored in separate directory trees.

Download Activities

Currently 65 IGS stations submit daily observation files to the „indata“ incoming directory at BKG. Nearly all stations send the files in Compact RINEX and compressed format. BKG receives combined GPS/GLONASS data of 15 IGEX stations and 19 German permanent stations. The data of the German stations are not public available. 10 IGS stations submit additionally hourly RINEX files for test purpose.

Online Data at BKG

IGS and IGEX data are online available for all users for at least 3 months. The data of the German permanent stations are processed at BKG and the results are online available, but not the original observations. Hourly data files are online available for a period of 3 days and older data are deleted successively. The account for all online data is:

- host: 141.74.240.26 (igs.ifag.de)
- user: anonymous

There are 3 directory trees for the different data types:

- /IGS (European IGS stations)
- /IGS/nrt (hourly RINEX data)
- /IGEX (combined GPS/GLONASS data)

Upload Activities

BKG performs routinely uploads of IGS, IGEX and hourly RINEX files to the Global IGS Data Center at IGN in Paris.

Future Requirements

Different GPS permanent networks show different specifications for the file format and name as well as for the site documentation file. This requires the strictly separation of files from different networks, e.g. the storage in separate directories. For the future only data of official IGS sites will be stored in the “IGS“ subdirectory at BKG. The hourly RINEX files for one complete day will be concatenated to a daily file and the quality and reliability will be compared to the quantities of the daily submitted files. If the hourly files can be used to successfully generate daily files, the transfer of daily files is no longer required.

Preliminary GPS Velocity Field Along the Cascadia Margin: The Pacific Northwest Geodetic Array (PANGA)

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Elliot Endo, Cascade Volcano Observatory, U. S. Geological Survey, Vancouver, Wash., USA;
Jeffrey T. Freymueller, University of Alaska, Fairbanks, AK USA;
Chris Goldfinger, Oregon State University, Corvallis, USA;
Harvey M. Kelsey, Humboldt State University, Arcata, Ca USA;
Eugene D. Humphreys, University of Oregon, Eugene, Ore., USA;
Robert McCaffrey, Rensselaer Polytechnic Institute, Troy, N.Y. USA;
John S. Oldow, University of Idaho, Moscow, ID USA;
Anthony Qamar, University of Washington, Seattle, Wash. USA;

After one year of operation, the Pacific Northwest Geodetic Array (PANGA) has accumulated enough data to generate a preliminary velocity field. During the last year the network has grown to daily analysis of 30 regionally distributed sites. Using absolute positioning, meaningful geologic and geophysical trends have not yet emerged, but are expected within the three years. Using baselines referenced to the well characterized IGS site at Penticton, British Columbia, interesting (although preliminary) trends emerge in both the fore arc and back arc. The motion of Quincy, in the Sierra Nevada, reflects 9 mm/yr northwestard motion accommodated along the Eastern California shear zone. North of the triple junction, sites in the arc and back arc show a diminished but persistent northwestward motion relative to Penticton. This pattern persists to central Washington west and south of the Olympic Wallowa line.

Along the coast, a different pattern emerges. Near the Mendocino triple junction at Cape Mendocino, the influence of the triple junction is expressed as approximately 19 mm/yr of NNW motion. Farther north at Cape Blanco, the competing signal of the locked Cascadia fore arc yields a lesser, NNE motion. Even farther north, coastal sites at Fort Stevens and Pacific Beach show northeastward convergence nearly parallel to the Juan de Fuca - North America convergence direction.

Recent Enhancements to the CDDIS

Carey E. Noll
NASA GSFC

Introduction

The Crustal Dynamics Data Information System (CDDIS) has served as a global data center for the International GPS Service (IGS) since its start in June 1992, providing on-line access to data from over 160 sites on a daily basis. Operational and regional data centers deposit data to the CDDIS several times per day; data holdings are then equalized among all global data centers (i.e., IGN and SIO). During 1998, approximately 45 percent of all data were available to users within one hour of the end of the observation day; 65 percent were available within three hours and 75 percent were available within six hours.

Each GPS site produces approximately one Mbyte/site/day of GPS data in compressed format. The CDDIS continues to make GPS data available in both compressed (O file extension) and compressed compact RINEX (D file extension) formats. UNAVCO's TEQC software is utilized on all incoming data to validate format and data quality. Metadata are extracted from the GPS data and an online database inventory is maintained to monitor all data received. Daily status files (an example shown in Figure 1 below) are generated with information extracted from the RINEX header, such as receiver and antenna type, antenna height, and hour delay in delivery.

Computer System Enhancements

Procurement of a replacement hardware platform for the CDDIS VAX system was undertaken in early 1997. This new system is a DEC AlphaServer 4000 running the UNIX operating system; the host name for this computer is cddisa.gsfc.nasa.gov. The system is currently equipped over 120 Gbytes of on-line magnetic disk storage; nearly ninety additional Gbytes of storage is on order. All GPS data activities were transferred to the UNIX platform by mid-1998. GPS data and products are now accessible on this system through anonymous ftp and the WWW. Over one year of GPS data are online; all products since the start of the IGS Test Campaign (mid-1992) are also online.

An area of ongoing concern to the CDDIS staff has been the ability to respond to special requests for older, off-line GPS data. Currently, this is a time-consuming activity for the staff since all older data are stored on optical disks in VAX VMS file format and the CDDIS VAX system is equipped with only two optical disk drives. The CDDIS AlphaServer system under UNIX is not equipped with these magneto-optical drives; therefore, a new medium for long-term storage of the historic GPS archive has been identified: CD-ROM. A CD recordable system and 600 platter jukebox were purchased

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IGS Tracking Network Status for 20-Oct-98 981020 98293    GPS Week 0980 Day 3         As of date:  Oct 28 1998 13:33:09

     Dly  No.   No.   Pts.     Avg. Avg. Pos.  No.                                             Ant.                       Marker
Site (H)  Exp.  Obs.  Del.  %  MP1  MP2  Diff Slps V    Receiver Type        Antenna Type     Height      Marker Name      Number
---- --- ----- ----- ----- --- ---- ---- ---- ---- - -------------------- -------------------- ------ -------------------- ---------
albh   1 20009 19358     0  96 0.41 0.76 0.05   44 1 ROGUE SNR-8000       DORNE MARGOLIN T      0.100 albh  WCDA-ACP   927 40129M003
algo   1 20338 18924    13  93 0.38 1.02 0.03   15 1 ROGUE SNR-8000       DORNE MARGOLIN T       .100 algo CACS-ACP   8831 40104M002
alic   6 22007 19262     0  87 1.23 1.91 0.11  755 1 ROGUE SNR-8100       DORNE MARGOLIN T      0.007 ALIC
amc2  26  3375  3105   187  92 0.32 0.78 0.04   11 1 ROGUE SNR-12         DORNE MARGOLIN T       .000 AMC2                 XXXXXXXXX
amct
amun   7 26139 26041    83  99 0.59 0.49 0.00   23 1 ASHTECH Z-XII3       DORNE MARGOLIN ASH    0.079 AMUN
ankr
aoa1   1 19835 17822   518  89 0.42 0.69 0.00   35 1 ROGUE SNR-8000       DORNE MARGOLIN T      0.000 AOA1                 40483S001
aoml   2 20935 17765   932  84 0.36 0.76 0.06   41 1 ROGUE SNR-8000       DORNE MARGOLIN T       .000 ATLANTIC OCEANOGRAPH 49914S001
areq   8 21429 14592  3847  68 0.26 0.74 0.00   98 1 ROGUE SNR-8000       DORNE MARGOLIN T      0.061 AREQ                 42202M005
asc1   2 23420  9394  7284  40 0.40 0.72 0.00  108 1 ROGUE SNR-8000       DORNE MARGOLIN T      0.067 ASC1                 30602M001
auck   2 20108 18328   135  91 0.24 0.69 0.00   19 1 ROGUE SNR-8000       DORNE MARGOLIN T      0.001 AUCK                 50209M001
azu1   2 19858 16762  1014  84 0.44 0.77 0.00   39 1 ROGUE SNR-8000       DORNE MARGOLIN T      0.081 AZU1                 49911M001
bahr   3 20933 18057    61  86 0.34 0.47 0.04   11 1 ASHTECH Z-12         DORNE MARGOLIN ASH    3.122 BAHR                 249010M02
bako 163 25130 21371   339  85 0.51 0.60 0.08  113 1 TRIMBLE 4000SSE      4000ST L1/L2 GEOD     1.676 BAKO                 TTG.1
barb
barh   2 20179 19533   329  96 0.29 0.81 0.46   47 1 TRIMBLE SSI          Trimble chokering     0.000 barh                 xxx
bogt   8 23590 12996  5240  55 0.42 0.89 0.00  117 1 ROGUE SNR-8000       DORNE MARGOLIN T      0.061 BOGT                 41901M001

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yar1   2 20012 18263   305  91 0.23 0.66 0.00   48 1 ROGUE SNR-8100       DORNE MARGOLIN T      0.081 YAR1                 50107M004
yell   1 22385 21554     1  96 0.48 0.76 0.03    2 1 ROGUE SNR-12 RM      DORNE MARGOLIN T       .100 yell CACS-ACP   8892 40127M003
zeck  22 21606 20021   132  92 0.36 0.61 0.06   20 1 ROGUE SNR-8000       DORNE MARGOLIN T      0.045 ZECK                 12351M001
zimm   6 20343 20089    50  98 0.30 0.67 0.07   19 1 TRIMBLE 4000SSE      4000ST L1/L2 GEOD     0.000 ZIMM                 14001M004
zwen  47 22741 20400     0  89 0.51 0.88 0.06   79 1 ROGUE SNR-8000       DORNE MARGOLIN T      0.046 zwen                 12330M001

Program:  QC V3 by UNAVCO run with elevation angle cutoff of 10 degrees
    Field      Size   Type                         Explanation
-------------  ----  ------  -------------------------------------------------------
Site             4   char    Site name
Dly (H)          3   number  Delivery delay in hours
No. Exp.         5   number  Total number of observations expected
No. Obs.         5   number  Total number of observations in file
Pts. Del.        5   number  Total number of points deleted
%                3   number  Data collection percentage
Avg. MP1         4   number  Average L1 multipath (rounded to two decimal places)
Avg. MP2         4   number  Average L2 multipath (rounded to two decimal places)
Pos. Diff        4   number  RINEX vs QC point position difference (Km)
No. Slps         4   number  Number of detected slips
V                1   number  Version of the data file (set to 1 for initial delivery)
Receiver Type   20   char    Type of GPS receiver from RINEX header
Antenna Type    20   char    Type of GPS antenna from RINEX header
Ant. Height      6   number  Height of antenna from RINEX header
Marker Name     20   char    Marker name from RINEX header
Marker Number   10   char    Marker DOMES number from RINEX header
```

Figure 1. Daily Status File Produced by CDDIS

in 1997. The CD recordable system consists of a Macintosh computer and a CD-ROM tower with the capability of recording up to five copies of a CD. Migration of the existing GPS archive on magneto-optical disks (in VAX/VMS format) to CD-ROM has begun. The data are written to CD-ROM by GPS week. Thus far, the majority of 1997 data are now on CD-ROM and are accessible through the jukebox.

Changes in the Data Archive

The CDDIS data and product archive directories were consolidated to a single file system accessible via anonymous ftp once the new computer was operational in mid-1998. This change has simplified data access for the user community since all data are now under one directory path.

In mid-1998, the CDDIS began providing the IGS user community with access to hourly data files. Hourly data from over thirty sites are transmitted to CDDIS from JPL, ESA, and IGN. The hourly data are archived on CDDIS in a timely fashion (e.g., within minutes of receipt) and are retained for three days. After three days, the hourly data are deleted; the daily file, transmitted through normal channels with typically a one to two hour delay, will have been received and archived already and thus the hourly data are of little use.

A Call for Participation in the 1998 International GLONASS EXperiment (IGEX-98) was issued in early 1998. IGEX-98 is sponsored by several organizations, including the IGS, and requested participation by stations, data centers, and analysis centers. The CDDIS responded to this call and was accepted as a global data center. On-line directories, accessible via anonymous ftp, for GLONASS data and products were established; the CDDIS currently archives data from over fifty stations participating in IGEX-98.

Changes in the Product Archive

Starting in early 1998, the IGS Analysis Center Coordinator began generating predicted orbit, clock, and Earth rotation parameter combinations based upon the individual ACs' predicted solutions. These solutions, designated IGP, are available within 0.5 hours of the beginning of the observation day. Also early in 1998, the IGS Analysis Center Coordinator began generating accumulated IGR and IGS ERP files on a daily and weekly basis; these data are used with either the final or the rapid orbits. These files are produced at the same time as the IGS rapid and final products are generated and downloaded by the IGS Global Data Centers.

The CDDIS began generating "short-SINEX" files, designated with an .SSC extension in early 1998. These files contain the site information from the SINEX file but no matrices. The files are stored in the weekly IGS product subdirectories.

Since January 1997, the IGS has conducted a pilot experiment on the combination of troposphere estimates. Using a sampling rate of two hours, the zenith path delay (ZPD) estimates generated by the IGS analysis centers were combined by GFZ to form weekly ZPD files for over 150 IGS sites. These troposphere products are available at the CDDIS starting in early 1998.

As of mid-1998, several IGS Analysis Centers began supplying daily, global ionosphere maps of total electron content (TEC) in the form of IONEX (an official format for the exchange of ionosphere maps) files. These products are also available at the CDDIS and are located in subdirectories of the main product area, rather than under the weekly subdirectory structure, since the files are produced daily.

Future Plans

The CDDIS staff plans to continue the migration of older GPS data to CD-ROM during 1999. One area under investigation is a common directory structure for data and products among all IGS data centers. This system would aid IGS analysis centers and users in navigation of multiple data centers. An extension of this plan is the participation of IGS data centers in the GPS Seamless Archive Center (GSAC) activity, sponsored by UNAVCO, and designed to allow easy navigation of multiple GPS archives for data of interest. Both activities will be investigated further to ascertain how best to implement the concepts within the CDDIS.

Contact Information

To obtain more information about the CDDIS, contact:

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The Data/Analysis Center OLG Austria

Th. Pany[1], P. Pesec[1], G. Stangl[2]

The OLG (Observatory Lustbuehel Graz) Data center was established 1994 as the official data center of CERGOP, a geodynamic project within section C "Geodesy" of the Central European Initiative, connected to IAG via the Subcommission "Geodetic and Geodynamic Programmes of the CEI" of IAG Commission VII, Section V. In addition, the data of 12 European IGS/EUREF stations are collected for analysis. 24-hour RINEX files are received, checked and distributed immediately after arrival, 1-hour RINEX files are distributed for selected stations within 30 minutes after creation. The Austrian permanent GPS-stations array operates on a primary sample rate of 1 second, RINEX-files of arbitrary sample rate are prepared by command. For the data handling two PCs and two UNIX workstations are at disposal. 30-sec RINEX data are stored in HATANAKA/UNIX compressed form unlimited (first on MO-disks and later on CDs), the last 100 days are available via Internet. 1-sec data are available for 60 days.

The OLG Analysis Center was established 1995. It uses Bernese Software 4.0 and own software products for carrying out computations of different networks: a EUREF sub-network ranging from Scandinavia to Cyprus (computed weekly); a regional network comprizing the Austrian and surrounding geodynamic permanent GPS-sites (computed weekly); a local network including all Austrian permanent GPS-sites (computed daily for station monitoring). The results are based on ITRF96 and computed according to EUREF standards. A new network is under construction which uses 1-hour data samples in quasi real-time for the estimation of tropospheric zenith-delays as input for a European weather forecast model (EU Project COST 716).

Data products are coordinates, covariancees, normal equations, zenith-delays and ionospheric models. Epoch-like campaigns have been computed on a regular basis (EUVN97, regional campaigns in earthquake regions, activities within the "Decade of Natural Disaster Reduction"), new dedicated campaigns will follow under the umbrella of CERGOP-2.

The investigations aim at the examination of the influence of processing standards on results (ambiguity fixing, a priori sigmas), the estimation of station velocities in Central

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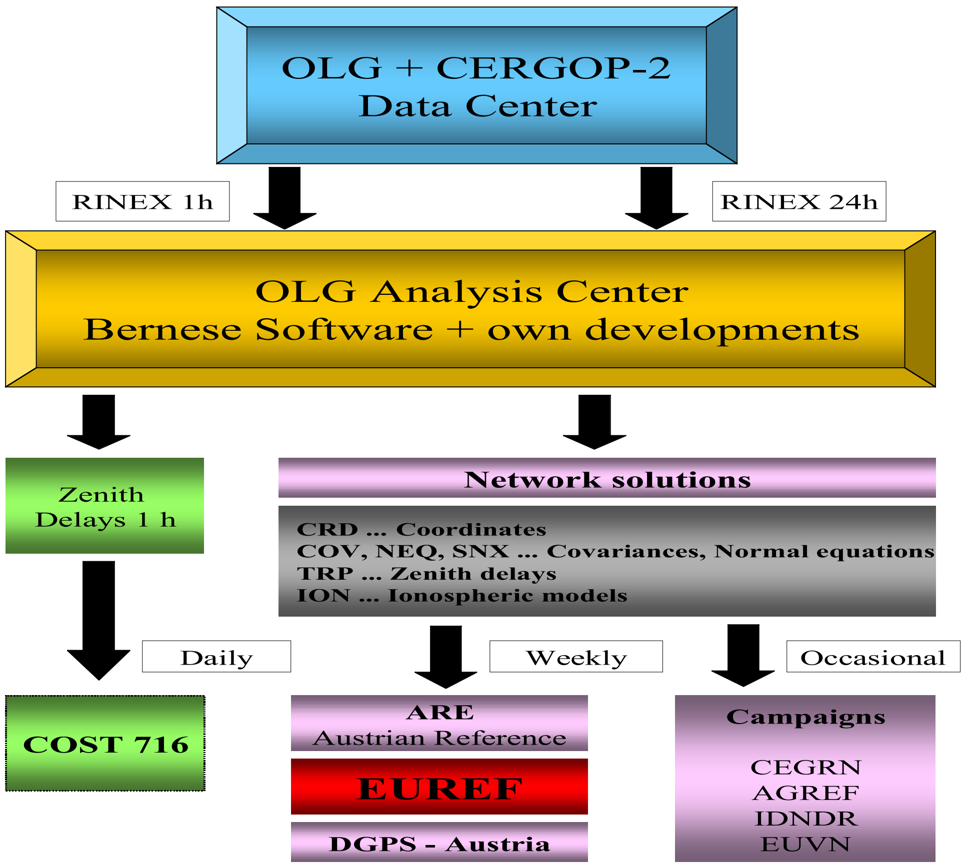
OLG PRODUCTS



Europe, and the reliability of tropospheric zenith delays. A special program concerns the detection of crustal movements along the boundary of the Adriatic Microplate and its northern edge, which is presently disturbed by ongoing seismic activities (earthquake of Easter Sunday 1988 in Western Slovenia).

First GLONASS experiences are seeked for in the ongoing IGEX-98 experiment. An Ashtech Z-18 is in permanent operation at the observatory Graz-Lustbuehel, first investigations will start in near future.

The Austrian dGPS Service places at disposal 2.1 RTCM corrections (code and phase) for civilian users via the Austrian Broadcast Company. OLG monitors the coordinates of the reference stations on a daily basis and carries out quality checks of the submitted RTCM data in real-time.

Can You Datamine GPS Data?

Joel Sachs, University of Maryland Baltimore County, Baltimore, MD
Jeanne Behnke (NASA Goddard), Dr. Kostas Kalpakis (UMBC)

Datamining is the automated discovery of patterns in data. It includes old statistical techniques, scaled to work on huge datasets, as well as new techniques motivated by such datasets. This poster described:

Association Rules Discovery

Let *I* be a set of items.
Input: a collection of subsets of *I* (called baskets).
Output: rules of the form A ==>B, where A and B are disjoint subsets of *I*.
The meaning of the rule is that baskets containing A are likely to contain B.

most famous application: shopping basket analysis.

Classification

Input: a training set, in which each entry consists of attributes and a class.
Output: a *classifier*, which is capable of specifying the class of future items based on their attributes.

example: the automatic classification of the Mt. Palomar Sky Survey.
(see http://cadcwww.dao.nrc.ca/ADASS/adass_proc/adass3/papers/djorgovskis/djorgovskis.html)

Clustering

Input: a collection of n dimensional vectors. (each dimension represents an attribute).
Output: a partitioning of the collection so that similar vectors are in the same cluster

example: clustering on-line users based on their surfing patterns.

Similar Time Series Analysis

Input: a collection of time series
Output: all pairs of similar time series.

Or

Input: a collection of time series and a specified target series.
Output: all time series similar to the target series.

Applicability to GPS

Since GPS data is time series data, it should be amenable to datamining. There are several interesting research issues involved. For example, one approach to finding similar time sequences is to apply the Fourier (or some other) transform to the sequences, and then clustering the transformed sequences (using only the fist k dimensions) based on their proximity.

But there are many choices for the transform, and there are many choices for the distance function used to compute proximity. The challenge is to choose a distance function that captures the notion of similarity in a particular domain.

There is, in general, no reason to think that "similarity" means the same thing for sequences representing seismic data as it does for sequences representing meteorological data.
Our goal is to build a system that allows relevant features of a data space to be easily identified, so that an appropriate distance function can be constructed.

The problem is related to data warehousing, since ideally we would like to mine globally rather than locally. (e.g. "Show me all receivers that experienced similar displacements to this particular receiver over the last 5 years.)

Please see www.cs.umbc.edu/~jsachs/datamining for a more detailed description of datamining techniques. Your input is very much invited, especially as it relates to difficulties you foresee in the mining of GPS data.

World Wide Web Based Distribution of GPS Data

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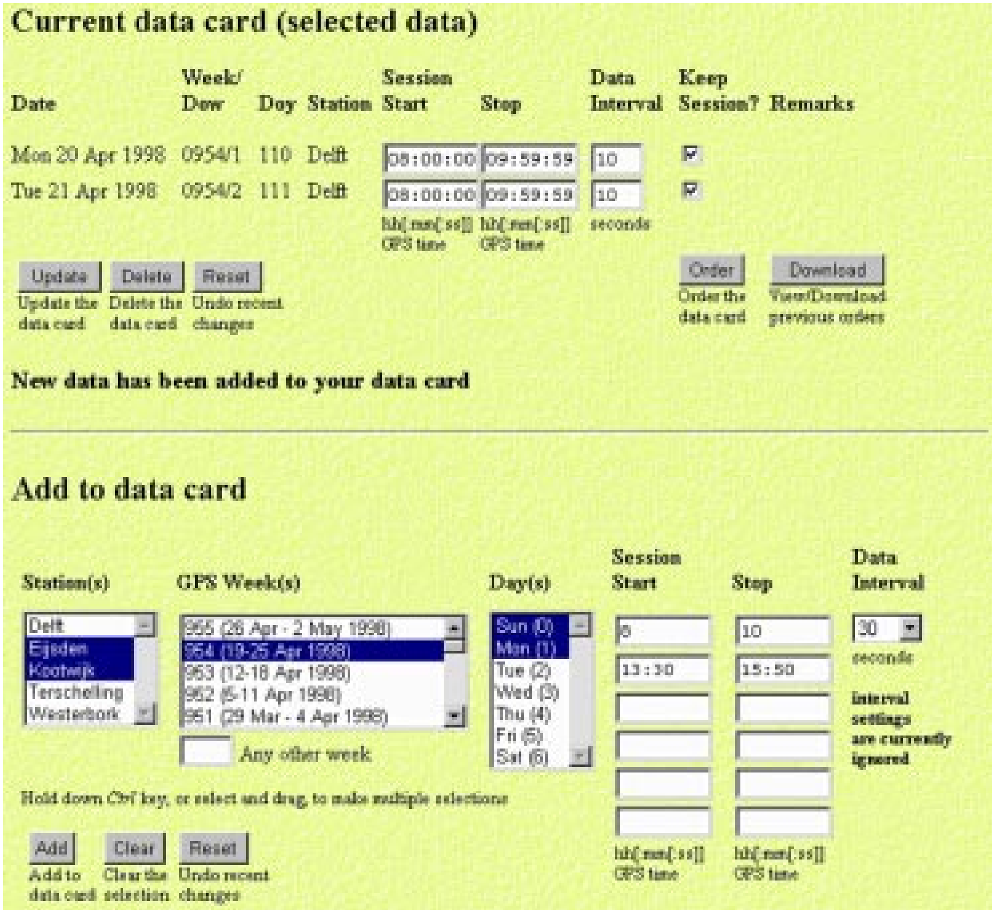
The Active GPS Reference System for the Netherlands (AGRS.NL) has two methods to distribute GPS data. The file transfer protocol (FTP) over Internet is used to download GPS data using daily and hourly (compressed) RINEX files. This method works well for automated and recurrent processing jobs, such as the daily processing for IGS and EUREF. However, professional users, who typically process a number of 15-30 minute sessions, prefer a more flexible interface which allows them to exactly specify the start time, stop time and data rate. Therefore, on October 23rd 1997 when the AGRS.NL became an official service to the Netherlands geodetic community, a World Wide Web (WWW) based data retrieval system was opened.

The WWW based data retrieval system consists of a general information area, on-line area, download area (registered users only) and project area (project team only). The on-line area is open to everybody and contains information on the current tracking status, current and past tracking performance and meteorological measurements, and time series of positions and water vapour. The download and project areas are open only to authenticated users and require a valid username and password. New users can register on-line and, in principle, gain immediate access to the download area, but since the AGRS.NL requires a fee this option has been disabled. The WWW system is implemented using a combination of static and dynamic generated HTML 3.2 pages. The dynamic pages are generated by server based Perl scripts. The system has been tested on NCSA, Apache and Netscape WWW servers running on different flavours of Unix. Porting to other WWW servers or the Windows environment and should not be difficult.

The download procedure uses an analogy with a shopping list, the so-called data card. The first step is to fill the data card. In a single action, several sessions for one or more stations can be added to the data card, while at the same time, already selected data can be removed from the data card or the interval and sample rate can be changed. This is repeated until one is happy with the selection (see figure). The next step is to place the order. As soon as the order is placed the data will be formatted into RINEX, compressed in zip files, and stored in the user's personal download area on the server together with previous orders. At the same time, the order is booked. The user can directly, or at a later time, download the compressed files. The data remains in the user’s download area for at least seven days.



The project area is only accessible to members of the project team. This area contains information and management tools for the project team. There are forms to change the welcome message on the AGRS.NL home page, to maintain a logbook and to change the user database. Also it is possible to get an overview of downloads. New entries in the logbook are mailed automatically to all members of the project team. New users can be added through a WWW form and existing entries can be changed, deleted and viewed. The WWW form is generated dynamically by a Perl script, which also maintains the user database for NCSA, Apache and Netscape servers. Three groups have been implemented: user, project and administrator. All groups have access to the download area. The project and administrator groups have access to the project area, but only administrators are allowed to change the user database. Also, when a user is added or changed, the project team and user receive an e-mail notification.

For more information visit http://www.agrs.nl.

IGS

NETWORK MONITORING

Remote-Controlled GPS Station Based on Ashtech GBSS Software

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The automatic downloading and data transfer as well as the remote control of a permanent GPS station are presuppositions to fulfil the requirements on an IGS station with regard to the data availability /1/. The new Ashtech Geodetic Base Station Software (GBSS) /2/ designed for continuous logging of high quality GPS data enables the automation of a station network.

Along these cornerstones an automatic and remote-controlled GPS station has been developed. Figure 1 shows the hardware and software components. The hardware components for the station are an Ashtech receiver, a notebook and a DC-DC converter assembled in a special rack with a battery-buffered power supply.

The software components of the station notebook run under the operating system WINDOWS NT 4.0. The installed logging software creates daily or hourly data files up to a 1 Hz sampling rate. The receiver and data storage parameters (sampling rate, elevation mask, directories, created files (binary, RINEX) etc.) can be set menu-driven. Special software tools and scripts are implemented to prepare the station for automatic data transfer, remote control and automatic restart after power interruption.

The FTP Daemon runs permanently to ensure the file transfer. If the station notebook can be connected to Internet using the LAN PC card, direct data transfer to the Operational Data Centre (ODC) can be performed. In such case the ODC software starts a FTP tool for automatic transfer.

In case of modem transmission via phone line with PPP (Point-to-Point Protocol), the autoRAS utility /3/ must be installed. It is a command line dial-up networking utility calling automatically a commercial provider or a remote PC. The remote PC acting like a provider is equipped with a PCMCIA modem and a LAN PC card for Internet. A specially designed UNIX script running under WINDOWS NT controls and supervises the dialling and the data transfer procedure via modem or Internet. A second UNIX script compresses the data and moves them to the transfer directory. The FTP tool transfers the data from provider to ODC.

For automatic restart after power interruption, the GBSS software and the UNIX scripts are put into the start-up folder. To overcome the WINDOWS NT login requirements the Tweak UI utility /4/ is used. It can be configured to automatically logon to the station notebook under a specific account and allows programs in the start-up folder to start when WINDOWS NT is started. Thus the station continues operation after power interruption.

The remote control of the station is performed by using the pc_ANYWHERE utility /5/. All software components of the station notebook can be remotely controlled by the ODC computer as long as both PCs are connected and running this software. At the station notebook pc-ANYWHERE is permanently running on stand-by waiting for access.

The remote control works also well with low transmission rates, for instance to South Africa or South America. The hourly data transfer with 1 Hz data is possible. The GFZ GPS and GLONASS stations equipped with this technique are working very stable.

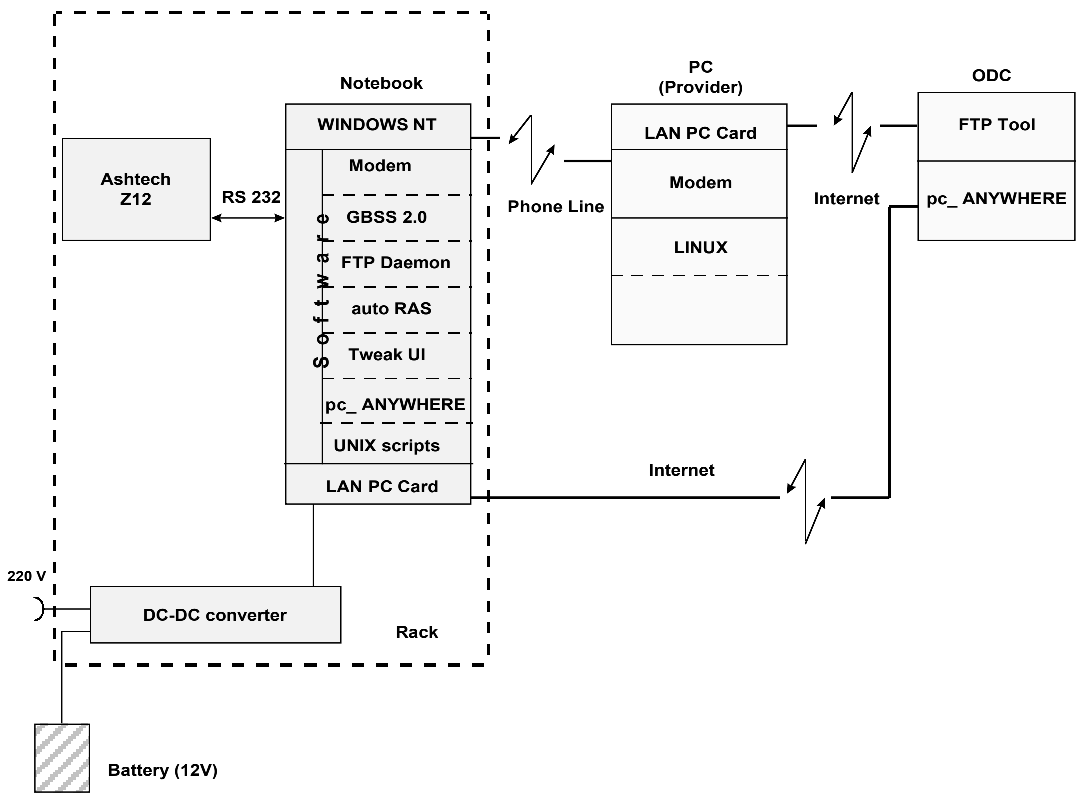

Figure 1: Hardware and software components of the remote-controlled GPS station

References

/1/ Standards for IGS Stations and Operational Centres
http://igscb.jpl.nasa.gov/network/guide_igs.html
/2/ Operations & Technical Manuel „Geodetic Base Station Software“, 1998
/3/ http://www.xorsystems.com
/4/ http://www.microsoft.com/windows95/info/powertoys.htm
/5/ Symantec pcANYWHERE „Users Guide“, 1988

Monitoring of the Austrian GPS-Stations Array

Th. Pany[1], P. Pesec[1], G. Stangl[2]

The Austrian network of permanent GPS-station presently consists of 9 stations which will be updated to a total of 11 stations during the next months. The establishment of this network has been a common effort of scientific, public, and private institutions, its aim leads from geodynamical investigations to the maintainance of reference frames and a service which supplies commercial users with RTCM code- and phase-corrections. 2 sites are operating as IGS core stations, 3 further stations are included in the EUREF and the CEGRN network. For maintainance reasons the design of the stations is mostly identical (TurboRogue, Trimble 4000SSI; Windows NT, GPSBASE), the fundamental station at Graz operates 3 receivers (TurboRogue, Trimble 4000SSI, Ashtech Z-18).

The station distribution was selected for an optimal coverage of the Austrian territory, keeping in mind geological aspects, cooperation with neighboring countries as well as minimizing distances of roving receivers. Careful attention was paid to protection provisions. All stations are equipped with high-voltage filtering devices and computer controlled UPS. Antenna shielding (radom) is provided for all public accessible sites.

Data products are delivered in a manyfold way. Based on a sample rate of 1 second RINEX-data as well as RTCM 2.1 corrections (including frame 18/19 and/or 20/21) are available. Part of these data will be commercialized, hourly data for tropospheric investigations can be forwarded for all stations in quasi-real time.

Data distribution is accomplished by the Austrian Broadcast Company (ORF), in addition spare connections (ISDN/analogue dial-up) are available for station monitoring and scientific applications (remote access service, remote communication). ORF places at disposal its powerful communication network in which all stations are routed via permanent ISDN lines. The RTCM corrections of all stations are collected at ORF (Vienna) and the monitoring center, flags are delivered to suppress bad data. RTCM corrections are modulated on the sub-carrier DARC, which allows for a data rate of 10 kBits/s required for the data-distribution (RDS only provides 1.1 kBits/s). The corrections are selectively distributed to the 18 main radio transmitters, a fall-back list replaces malfunctioning stations.

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Tel: +43316322607, Fax: +433163210914, e-mail: stangl@flubiw01.tu-graz.ac.at

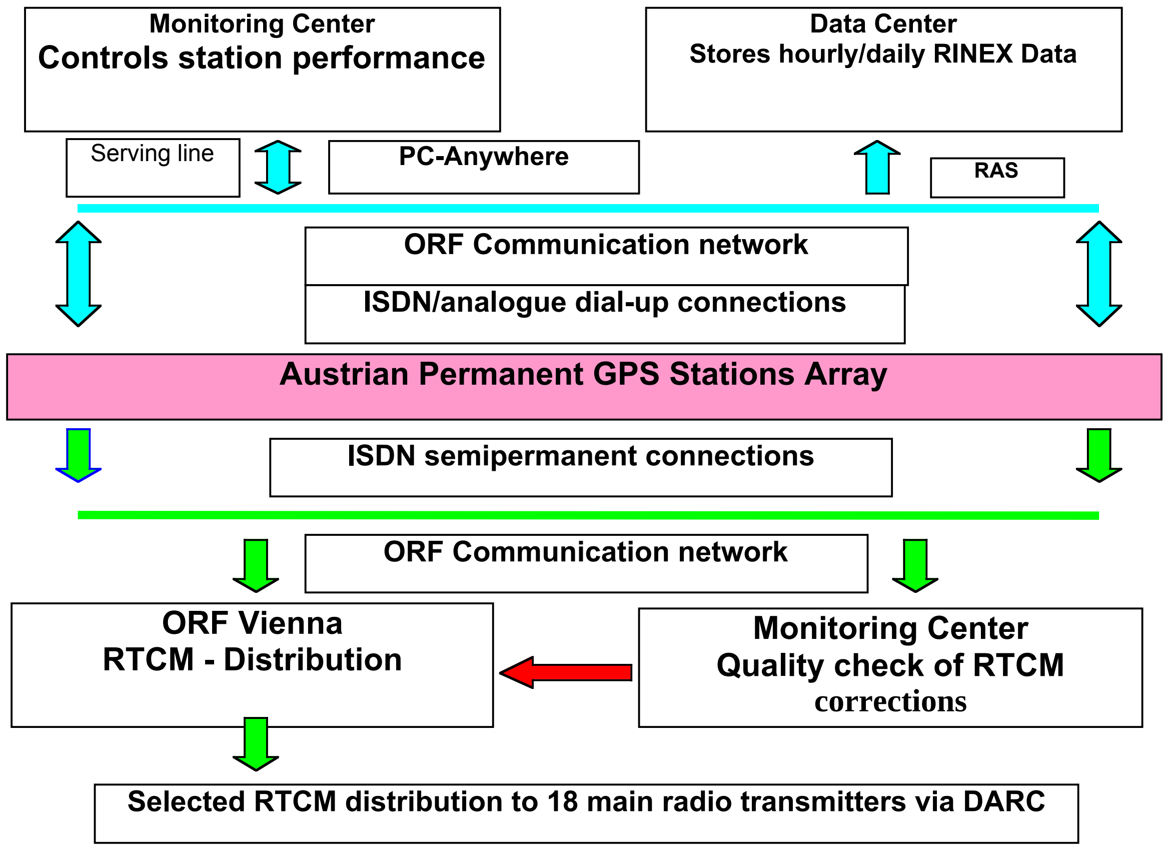

Figure 1: Illustration of the RTCM and RINEX data- and control-flow based on ISDN-RAS – TCP/IP

Quality monitoring is the most important item for satisfying paying users. RTCM corrections are collected in real-time, and checked at a calibrated station. The distributed corrections of all stations are compared with theoretically valid values. Fault-flags take the necessary steps to iniate the fall-back list which hands over the data distribution of a faulty station to the geographically nearest healthy station. They also give the necessary informations for an immediate station repair via mobile phone using the Short Message Service.

The Austrian dGPS Company takes care of the marketing of GPS-products in Austria. The data are provided by the Austrian Academy of Sciences (as a spin-off product of the 4 scientific stations GRAZ, PFAN, PATK, SBGZ) and the GPS-Net Company (a common undertaking of civil engineers; WIEN, LINZ). The Federal Office of Metrology and Surveying operates two further stations in Villach and Vienna, it is expected that these stations will also contribute in the near future. Two further stations will complete the full coverage of Austria. By end of 1999 it is expected that the Austrian GPS-station network can enter a self financing status.

Monitoring of the Dutch Active GPS Reference System

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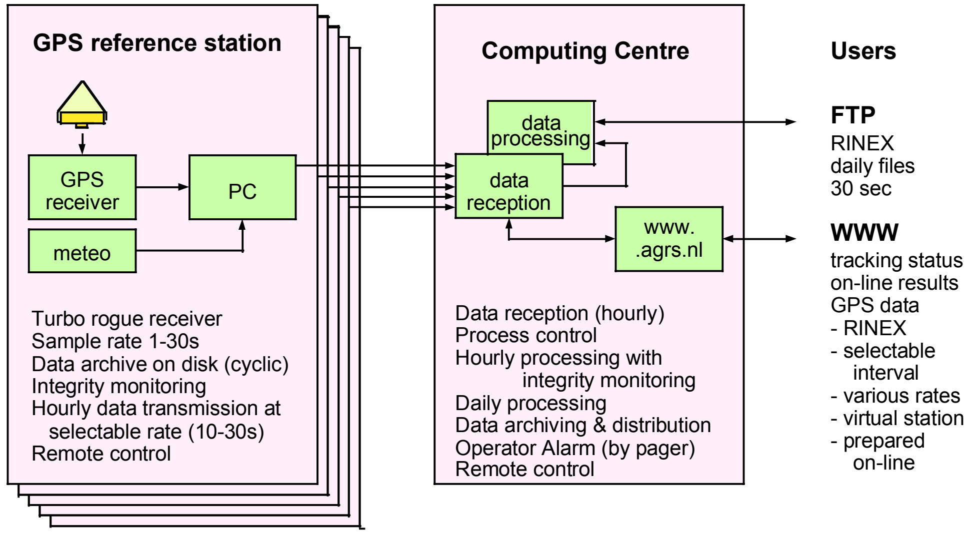
The Active GPS Reference System for the Netherlands (AGRS.NL) consists of a network of five permanently operating GPS receivers and a computing center. The locations of the reference stations were selected for research purposes. A good connection to other techniques, such as Satellite Laser Ranging and VLBI, points of the existing primary (height) control networks and tide gauges at the North Sea coast were important. The full network is in operation since the beginning of 1997 and has been used as the backbone for the Fifth Primary Leveling of the Netherlands in 1996-1998, international projects, atmospheric water vapor retrieval and geodetic research. The stations Kootwijk and Westerbork also participate in the IGS network. The AGRS.NL became an official service to the Netherlands geodetic community on 23 October 1997 and is now also used directly for reference frame maintenance, surveying and remote sensing applications. The operational activities of the AGRS.NL are since then being taken care of by the Cadastre and the Survey Department of Rijkswaterstaat. The Delft University of Technology is responsible for all research related to AGRS.NL and for the further development of the system.

The AGRS.NL has been designed from the start to support research and professional applications equally well. The professional applications set the standards for the availability, rate, latency and integrity of the data, from which research applications also benefit. A personal computer, connected to the GPS receiver, is used for the (remote) control of the receiver, to store GPS and meteorological data, to check the quality of the data and to transmit the data to a computing center (see the figure). Data is sent to the computing center at regular intervals, but also a continuous transmission is possible for real-time applications. The download interval, presently one hour, can be selected in the software. The sample rate of the receiver and transmission rate of the data stream to the computing center can be selected independently. The sample rate of the receivers is currently 10 seconds, but only 30-second data is sent routinely to the computing center. Occasionally reference stations switch to a 1-second sample rate and/or a 10-second data transmission rate. Data at the original sample rate is stored for a limited period (currently 1-2 months) at the reference stations. The final archive, with backup facilities, is located at the computing center.



The real-time quality control and integrity monitoring at the reference stations is based on a single channel approach and is independent of broadcast orbits and station locations. The quality control algorithm uses a Kalman filter based Detection, Identification and Adaptation (DIA) procedure. An elevation dependent stochastic model is used. In case the software detects problems, the software will flag the data or alert the operator by dialing a pager. Also, if the data fails to arrive at the computing center within a certain time limit (10 minutes), the operator is paged from the computing center. The quality of the data is checked a second time at the computing center using a – more powerful - network adjustment with hourly and daily data batches. The hourly batches are used to check the stability of GPS antenna positions, quality of GPS satellites, broadcast orbits, code and phase observations (cycle slips and outliers). In particular cycle slips can be corrected, and outliers, unhealthy satellites and GPS receivers with problems are removed. The daily processing (using precise IGS orbits) is used to derive accurate time series of positions and estimates of water vapor. Other functions of the computing center are data archiving and distribution of the data via the Internet using FTP and the WWW. For more information see http://www.agrs.nl.

IGS

NETWORK UPGRADE ISSUES

Distributing Tailored RINEX Data by Means of Virtual GPS Reference Stations

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Rapid and fast static GPS, using short observation time spans and on-the-fly ambiguity resolution techniques, are very popular among professional GPS users. Unfortunately, there is a distance limit of about twenty kilometers. It is possible to use these techniques over longer distances by using data from several reference stations in a network mode, although this is not a practical approach. The reason is that the processing is more complicated, users might not have the necessary software and expertise, it's necessary to download more than one reference station and the processing takes more time. This is where the virtual reference stations step in. Instead of downloading data from several reference stations, the user downloads data of a single non-existent virtual reference station in the neighborhood of his project.

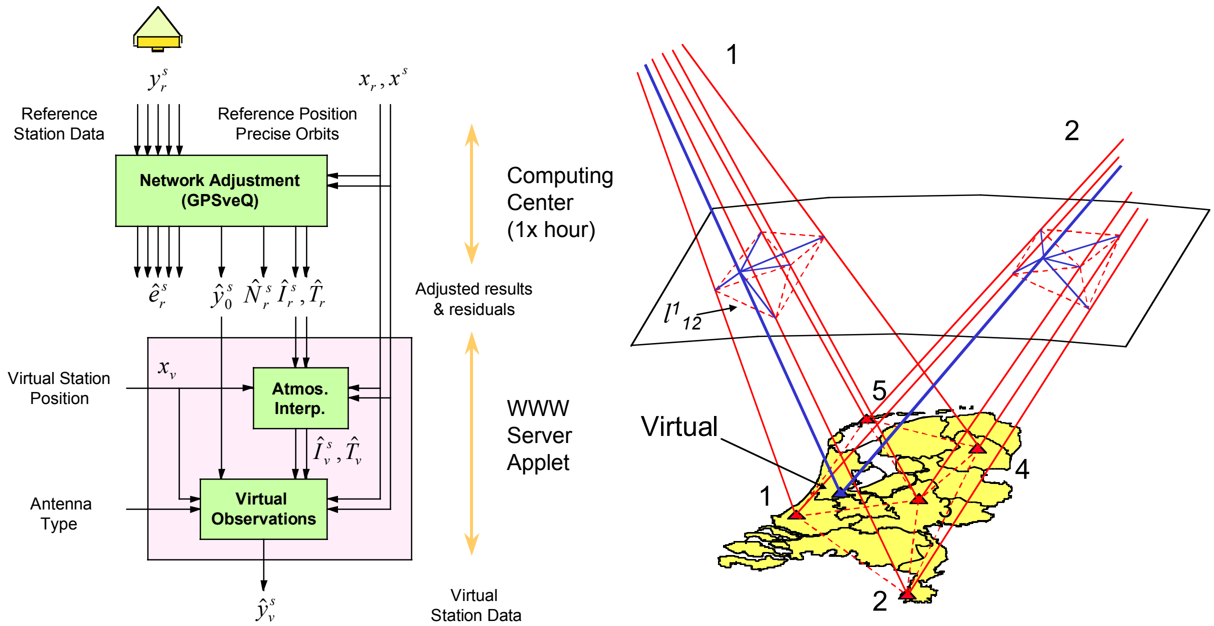
The virtual GPS reference station imitates as best as possible a real station at the specified location, including atmospheric and antenna phase center delays. The following procedure is used to compute virtual station data (see figure):

1. Network adjustment of the reference station data, resulting in adjusted observations, atmosphere and other parameters with their covariance matrix,

2. Computation of the virtual station data from the adjusted observations, including interpolation of atmospheric delays to the virtual location and corrections for the antenna type.

The network adjustment has to be done only once, but the virtual station data has to be computed every time some data is requested, e.g. from the WWW interface. The user may select the position and antenna type for the virtual station. The virtual station data for the selected position is given in the RINEX format. The tropospheric zenith delay and ionospheric delay for individual satellites are interpolated to the virtual location (see figure). As the user will typically select a virtual station close by, he may use his favorite GPS software for short baselines with integer ambiguity resolution. Although the computing center uses precise orbits to reduce orbit errors, the user can simply use broadcast orbits.

Virtual GPS reference stations combine the power and strength of a network solution with the comfort of a baseline solution. The results are comparable to a network solution with all reference stations constrained to known coordinates. However, with the virtual station approach, the network of reference stations has to be computed only once and only data for one virtual reference station, for the duration of the measurements, is needed. Furthermore, atmospheric delays are interpolated to the virtual station, and therefore standard - commercially available software – and broadcast orbits can be used. It is not necessary (nor desired) to form the ionosphere free linear combination and it is sufficient to process only virtual L1 data, resulting in



a more reliable ambiguity resolution and shorter observation times. Compared to a baseline solution, using the nearest reference station, virtual reference stations have the quality, availability and reliability of a network solution. Only data that has been checked is used. Also, improvements and new models have to be implemented only at the computing center.

For more information see: H. van der Marel (1998), *Virtual GPS Reference Stations in the Netherlands*, In: Proceedings ION-GPS 98, Nashville, Tennessee.

IGS

OTHER

CORS on the Web

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National Ocean Service, NOAA
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Abstract

A poster compiled by the National Geodetic Survey (NGS) displayed their Continuously Operating Reference Station (CORS) Web site (http://www.ngs.noaa.gov/CORS/cors-data.html)This Web site allows users to retrieve GPS ephemerides; GPS data, log files, coordinates, statistics and velocities for the CORS; maps of CORS coverage; newsletters; CORS articles; frequently asked questions; personnel contacts; software; and links to IGS and other related sites. In addition to these basics, the poster exhibited pictures of several CORS sites to show their variety. Descriptions and displays regarding other items available on the Web page included: GPS Meterology; the developing Nationwide Differential GPS (NDGPS), a Real-Time Positioning and Navigation system; and the current Antenna Calibration (NGS) program. A brochure was available showing excerpts from the Web site.

ESOC GPS SITES

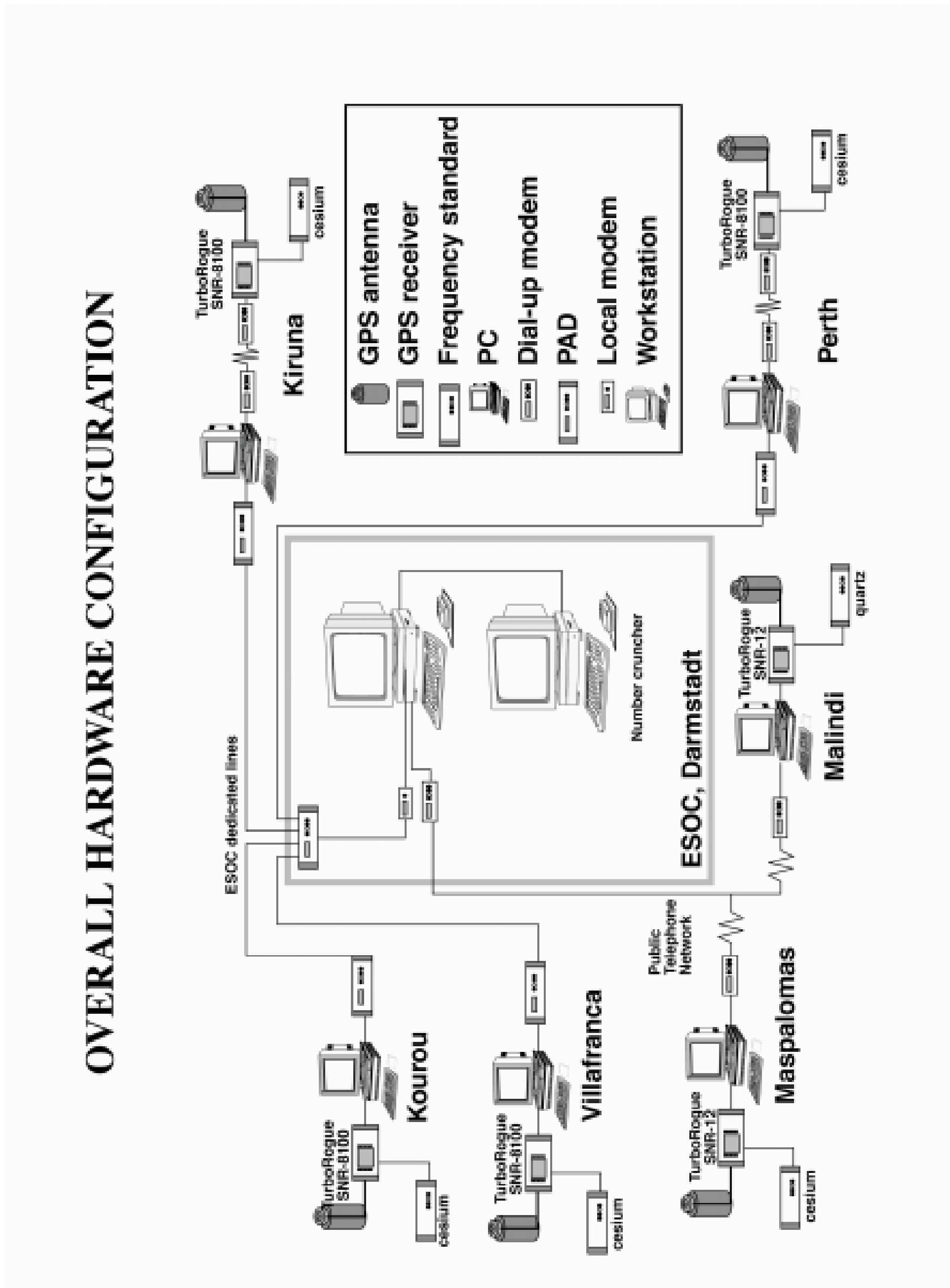
NETWORK SYSTEMS WORKSHOP

ANNAPOLIS, MD

NOVEMBER 2-5, 1998

Joachim Feltens (EDS at ESOC),Pelayo Bernedo (GMV at ESOC).

ESA GPS SITES. GEOGRAPHICAL DISTRIBUTION.



OVERALL HARDWARE CONFIGURATION
Kiruna
TurboRogue SNR-8100
cesium
GPS antenna
GPS receiver
Frequency standard
PC
Dial-up modem
PAD
Local modem
Workstation
Perth
TurboRogue SNR-8100
cesium
ESOC dedicated lines
Number cruncher
ESOC, Darmstadt
Malindi
TurboRogue SNR-12
quartz
Public Telephone Network
Kourou
TurboRogue SNR-8100
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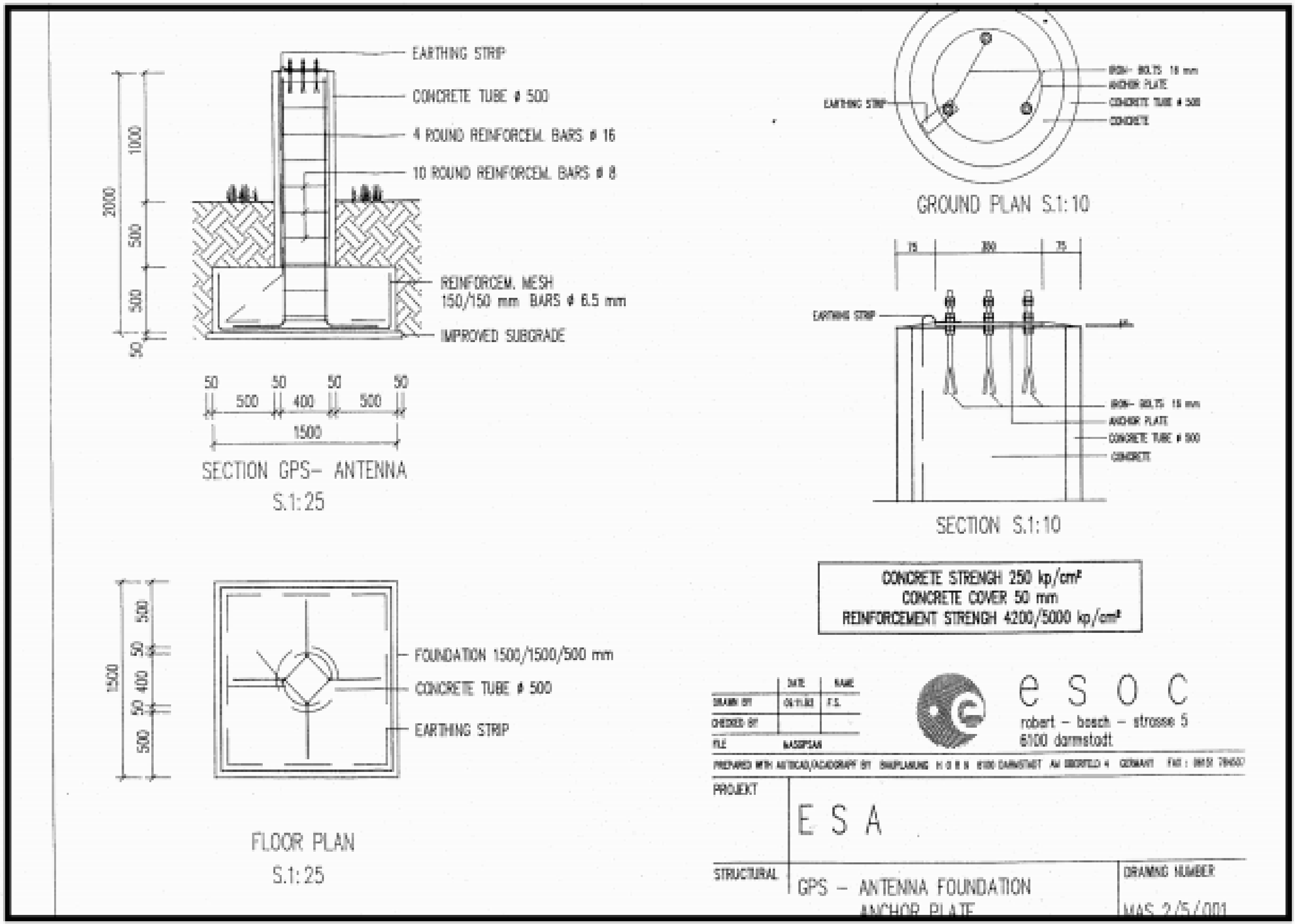
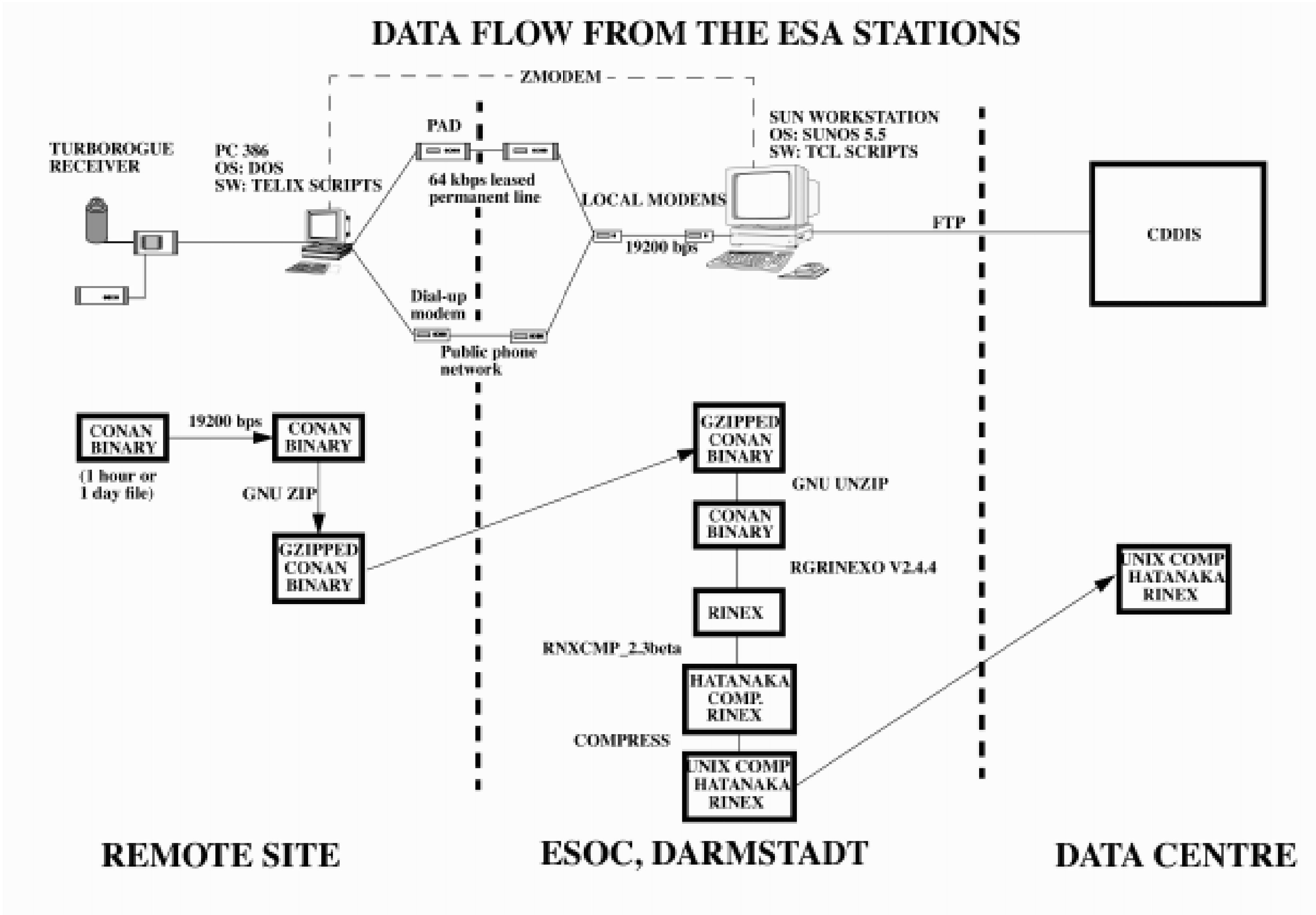
GEODETIC MONUMENTS DESCRIPTION




DATA FLOW FROM THE ESA STATIONS
ZMODEM
TURBOROGUE RECEIVER
PC 386
OS: DOS
SW: TELIX SCRIPTS
PAD
64 kbps leased permanent line
Dial-up modem
Public phone network
LOCAL MODEMS
19200 bps
SUN WORKSTATION
OS: SUNOS 5.5
SW: TCL SCRIPTS
FTP
CDDIS
CONAN BINARY
(1 hour or 1 day file)
19200 bps
CONAN BINARY
GNU ZIP
GZIPPED CONAN BINARY
GZIPPED CONAN BINARY
GNU UNZIP
CONAN BINARY
RGRINEXO V2.4.4
RINEX
RNXCMP_2.3beta
HATANAKA COMP. RINEX
COMPRESS
UNIX COMP HATANAKA RINEX
UNIX COMP HATANAKA RINEX
REMOTE SITE
ESOC, DARMSTADT
DATA CENTRE

1-HOUR DOWNLOADS

The new system required upgrades to:

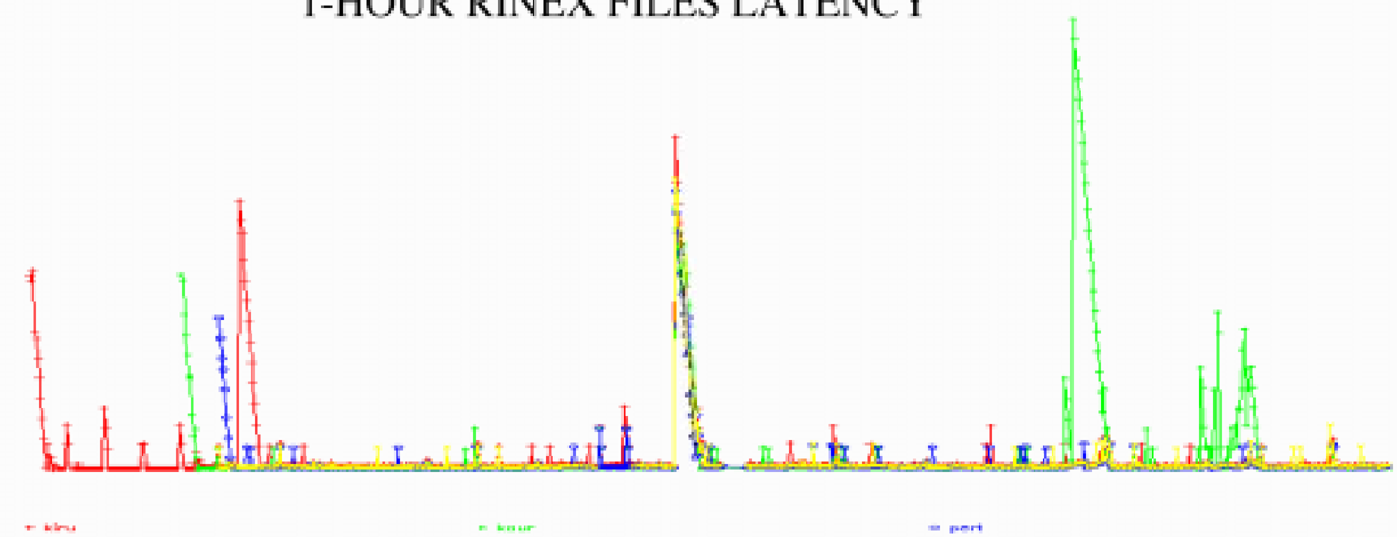
The software of the station PCs to download and store data every hour

The software of the control centre to retrieve, preprocess and distribute the data

Kiruna was upgraded on September 15th, 1998 and a week later Kourou, Perth and Villafranca (stations with 64 kbps permanent leased lines).

The data are currently used for the rapid orbits and will be used in the future to reduce the propagation interval of the predicted orbits from 48 hours to 24 + computation time.

1-HOUR RINEX FILES LATENCY



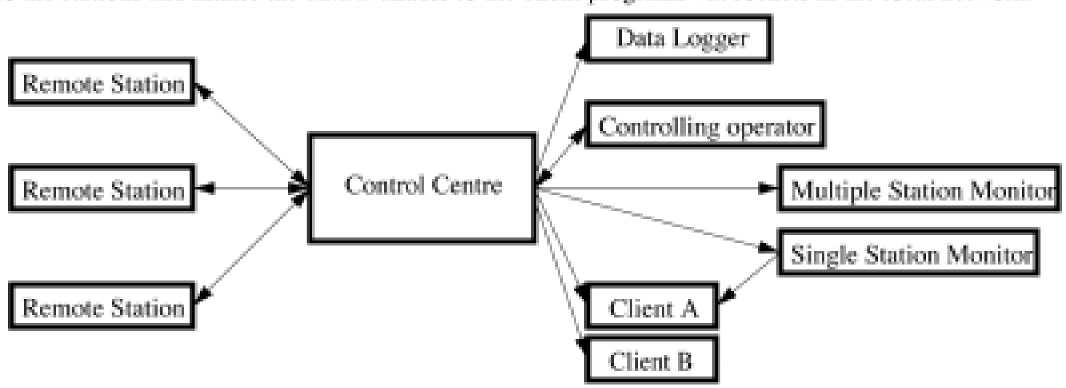
FUTURE DEVELOPMENTS

The PCs at the stations will be upgraded according to new systems requirements: near real time retrieval, network changes in Kourou and Perth next year. Windows 95 will be installed at Kourou because of local network requirements.

REAL TIME

A real time system has already been developed in C++. It is made up of the following parts:

1. The station computer software. It makes a supervision of the receiver, stores locally the measurements, converts them to receiver independent format for real time and sends them to the Control Centre with integrity checking.
2. The data links must support at least 300 bytes/second for 1 Hz operation.
3. The Control Centre at ESOC receives the measurements and the status of the stations in real time, can also send commands to the stations and makes the data available to the client programs via sockets in the local network.



IGEX DATA TRANSFER

Three Leeds receivers participate in the campaign:

LDS1: GPS + GLONASS two frequency receiver. ESA development.
LDS2: TRIMBLE 4000 SSE. GPS data.
LDS3: ASHTECH GG24EC. GPS + GLONASS data.

The campaign was started on October 19th, 1998 (DOY 292).

NIMA and U.S. Air Force GPS Tracking Networks

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The U.S. Department of Defense has two permanent GPS tracking networks. One is maintained by the U.S. Air Force and performs upload functions in addition to receiving broadcast navigation messages and telemetry. The tracking data are used by the Air Force's Master Control Station to compute the broadcast orbits and clock corrections and monitor satellite health. The National Imagery and Mapping Agency (NIMA) maintains an independent global network of stations which supply data for computing the WGS 84 precise GPS ephemerides, define the WGS 84 reference frame, and are used for quality control purposes by the Air Force.

The Air Force monitor station network consists of five stations in Colorado, Hawaii, Ascension Island, Diego Garcia, and Kwajalein. Data from the stations are transmitted to the Master Control Station in Colorado Springs, Colorado in real-time for processing. Efforts are underway to upgrade the computer and receiver equipment at the Air Force stations but no specific implementation date has been set. An additional Air Force station is planned for Cape Canaveral, Florida, but its operation is tied to the completion of the Air Force network upgrades.

NIMA currently has nine permanent monitor stations and a tenth station due to be operational in South Africa in 1999. The monitor stations are located in:

- Eielson Air Force Base, Alaska
- Buenos Aires, Argentina
- Salisbury, Australia
- Bahrain
- Beijing, China
- Quito, Ecuador
- Newbury, England
- Wellington, New Zealand
- Pretoria, South Africa (operational in 1999)
- Washington, D.C., U.S.A

All the stations use dual-frequency Ashtech receivers and cesium clocks. The U.S. Naval Observatory station in Washington, D.C. is connected to a hydrogen maser clock. The following table shows the configuration in place at each station:

STATION	RECEIVERS	CLOCKS
Alaska, U.S.A.	1	1 Cesium
Argentina	2	2 Cesium

STATION	RECEIVERS	CLOCKS
Australia	2	2 Cesium
Bahrain	2	2 Cesium
China	1	1 Cesium
Ecuador	2	2 Cesium
England	2	2 Cesium
New Zealand	1	1 Cesium
South Africa	1	1 Cesium
Washington, D.C., U.S.A.	2	1 Hydrogen maser

Data communications with these sites are done using dial-up modems at 19,200 baud. The station operations are automated. Data retrieval is initiated by a telephone call from NIMA's facility in St. Louis, Missouri. Both 30-second observations and observations smoothed to 15-minute epochs are collected from all the sites. Data are downloaded at least once a day from each site, but can be retrieved more frequently if required. Selective Availability effects are removed from the data in St. Louis. Quality control is performed in St. Louis to check the data before they are used in orbit processing or distributed to customers.

Recently, the data communications links to four of the stations -- Argentina, Australia, Bahrain and Washington, D.C. -- have been upgraded to allow near-real-time retrieval of data at up to 56K baud. Similar upgrades are planned for England and Ecuador. This will allow the Air Force to use NIMA's tracking data directly in orbit computations at the Master Control Station, and thus improve the quality of the broadcast orbits and clock predictions.

NIMA is hoping to further expand its tracking network by deploying additional stations in the Southern Hemisphere in places where the Department of Defense has no coverage. This is expected to help improve the accuracy of the broadcast and precise WGS 84 orbits, as well as provide improved redundancy in the tracking of the satellites. This will aid in error detection and analysis, and protect against the loss of data in the event of a station failure.

Northern Eurasia Deformation Array (NEDA)

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Project RUSEG (Russia/US Experiment on Geodynamics by GPS Technology) is performed since 1995 jointly by the Russian Academy of Sciences and Lamont-Doherty Earth Observatory, and it is supported by IRIS Consortium and by JPL. We describe here the contribution of RUSEG to the improvement of the IGS network over northern Eurasia (Fig. 1), and to better understanding of the plate tectonics.

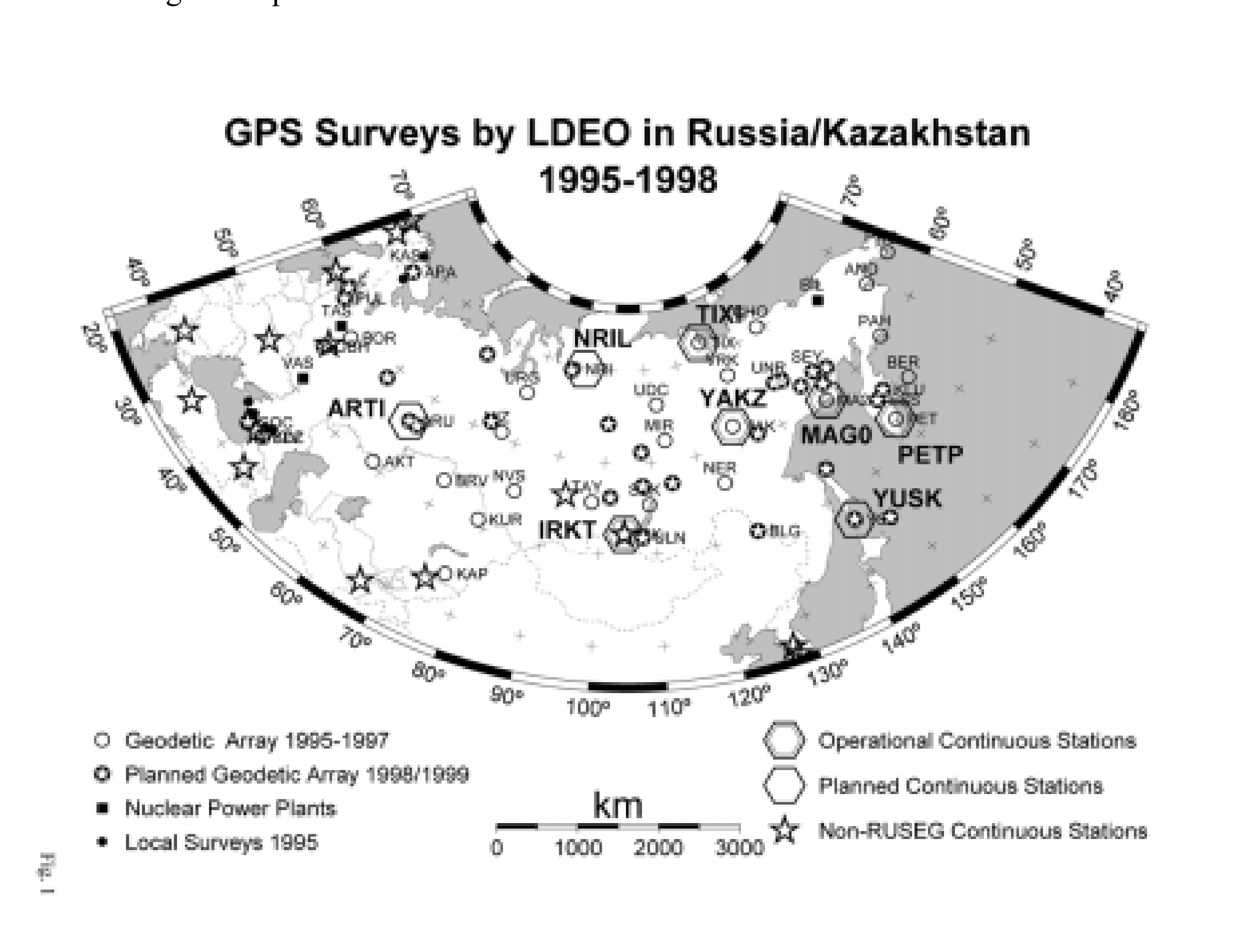

Figure 1. GPS Surveys by LDEO in Russion/Kazakhstan 1995-1998

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Prior to RUSEG, there were only two permanent GPS stations in Russia over the vast region to the east of the Urals Ridge: IRKT and KSTU, both close to each other, near Mongolia. Since October 1997, we established four new IGS stations in eastern Siberia (YAKZ/YAKA), Arctic(TIXI), and the Pacific margin (MAG0 and PETP) which improve dramatically the geometry of the global IGS polyhedron.

All RUSEG IGS stations are connected by Internet with the central computer of the Regional Data Acquisition and Analysis Center, Moscow (RDAAC) which transfers the data to Global IGS Centers. Daily receiver-format files are downloaded to local computers at our stations in an automated regime. Continuous tracking for the last 16 months showed RMS deviation of about ±5 mm in horizontal components and about twice as much vertically. Slow variations in all three components with a period of ~1 year and an amplitude of ~10 mm occur at all RUSEG stations. They are highly correlated between all four stations which may be attributed to an unknown error in satellite orbits, or in ionospheric and/or tropospheric signal delays.

We used the GAMIT/GLOBK software to process 2.5 years of RUSEG data (campaign-style observations of 1996 were included as first epoch) and to adjust it together with the GPS data from the Scripps global solutions since 1992. Inversion for plate rotations showed that our Euler pole Eurasia/North America departs significantly from that of NUVEL-1A.