GLONASS APPLICATIONS IN ANTARCTICA

GIANT action item 11 at the Heppenheim coordinators meeting was: To prepare a paper on the future of GLONASS beyond the IGEX meeting in September 1999.

Background

GLONASS was initiated in 1982 and built to a full constellation of 24 satellites within five years. However since that time problems have been encountered in the satellites, frequently through failures in the power supply elements and in June 2000 there are only eight operational satellites.

Russia however has pledged to sustain the GLONASS system and a number of new satellites are planned for launch later in 2000.

Whilst the success of the GPS has been overwhelming it needs to be kept in perspective that there are many areas where only a very limited number of GPS satellites are available due to geographic or operational constraints. Supplementation of the GPS with GLONASS for navigation purposes offers a great deal to these “back hole” areas. The combined use of GLONASS and GPS for Antarctic navigation is a powerful benefit for air land and marine operations in the Antarctic.

The international community began to address coordination and global use of GNONASS in 1998 and the International GLONASS experiment (IGEX) was commenced in 1999 with some 25 countries involved. The SCAR WG-GGI attempted to establish a framework of GLONASS receivers across Antarctica but only achieved one unit installed temporarily for two months at McMurdo early in 1999.

At the 1999 Institute of Navigation meeting on IGEX, despite the low number of satellites, the international community decided to go ahead with plans to support the activity of the GLONASS system and generation of products and services for users. It was decided to extend this experiment for three years and IGS took on the central bureau role to provide a service of data and products. A new call for participation has been circulated calling for countries and organisations to take on a data supply or processing or product generation role. The new program is named IGLOS

There are now two permanent continuous GLONASS receivers installed in Antarctica as part of the GIANT program. These are:

- Davis
- McMurdo

Southern Hemisphere laser ranging to the satellites is ongoing at Stromlo and Yaragadee in Australia as all GLONASS satellite carry retro-reflector arrays.

The benefits from GLONASS accruing to Antarctic operations are improved accuracy and coverage of satellite positioning, whilst the immediate benefits to Geodesy are not yet defined. These will evolve over the life of the new IGLOS project, but already provide interesting comparisons between radio metric and optical satellite orbit determinations ie

- SLR-GLONASS (all satellites)
- SLR-GPS (two satellites)

In summary the GIANT program supports the new IGLOS experiment and Meta data will be added to the web site.

A detailed history of the IGEX was presented at the joint ION/IGS meeting at Nashville in September as in the relevant papers from James Slater and Carey Noll, attached as Annex 1. A copy of the new IGLOS 'Call for Participation' appears as Annex 2.

J. Manning
L. Hothem
13 June 2000

Annex 1

IGEX-98 WORKSHOP

The IGEX-98 Workshop held on 13-14 September in Nashville, Tennessee was a great success. Approximately 80 people attended. I want to thank all the members of the Steering Committee and the Workshop Organizing Committee for their efforts in planning and coordinating the campaign, and the workshop that followed. Carey Noll was invaluable as the Co-chair of the Workshop as was Pascal Willis, Chair of the Steering Committee. The other members of the committees were Gerhard Beutler, Werner Gurtner, Guenter Hein, Wlodzimierz Lewandowski, Pratap Misra, Ruth Neilan, and Robert Weber. Thus far, only two-thirds of the papers have been submitted for publication in the workshop proceedings. If you are the author of one of those papers that has not been submitted yet, please submit it as soon as possible to the IGS Central Bureau web site http://igscb.jpl.nasa.gov/submissions/index.html.

IGEX-98 Highlights

The accomplishments of the experiment surpassed our expectations. Each individual and group that participated contributed directly to this success.

- A global network of over 60 GLONASS tracking stations and 30 Satellite Laser Ranging observatories in 25 countries participated in the campaign.
- Six months of continuous data were collected by these stations and archived at NASA Goddard Space Flight Center (GSFC) and the Institut Geographique National (IGN). This data set is a valuable asset that is available for use by anyone.
- Precise orbits were computed, from both the SLR and GLONASS receiver data, by 11 different groups, with resulting accuracies of 20-50 cm. A combined orbit was computed at the University of Technology, Vienna from the individual solutions provided on a regular basis by a subset of these groups. The precise orbits are also archived at NASA GSFC and IGN.
- Three commercial manufacturers and one university produced dual-frequency GLONASS receivers, which were operated and given their most thorough testing and evaluation as a result of IGEX.
- A number of different software packages (e.g., BAHN, Bernese, GIPSY) that were designed for GPS observations can now process GLONASS data and compute GLONASS orbits routinely.
- The RINEX and SP3 data exchange formats have been expanded to included GLONASS data.
- Datum transformations relating PZ-90 to WGS 84 and ITRF reference frames were derived by several groups for the first time with a global distribution of data.
- By utilizing the precise orbits, the ability to perform inter-continental time transfer was improved significantly.

A summary of IGEX-98 and some of the results presented at the workshop are in a paper that was given at the Institute of Navigation GPS-99 conference that followed the IGEX-98 Workshop in Nashville. A copy of this paper, titled “The International GLONASS Experiment (IGEX-98): Organization, Preliminary Results and Future Plans”, can be found in the IGEX web site under www.ion.org/workgroup.html. A list of workshop participants is also available at that web site.

Current Network Status and Potential Applications of GLONASS

As of today, there are 11 healthy GLONASS satellites. Thirty-one (31) stations continue to track these satellites and send the data to the Global Data Centers on a voluntary basis. Several groups continue to compute precise orbits using these data, and the timing community is applying these orbits in their time transfer work. Two of the manufacturers of dual-frequency GLONASS

receivers confirmed at the workshop that they will continue to make receivers available and will support the ones that are already operational.

Now that we have overcome the major obstacles that limited the use of GLONASS in the past, there are a number of applications that could benefit from the availability of GLONASS observations and orbits. These include atmospheric studies, geodesy, definition of the ITRF, force modeling studies, time transfer and orbit prediction. The combined GPS and GLONASS constellations are also a good model for future Global Navigation Satellite Systems that may consist of several independent, integrated satellite systems. Many potential applications take advantage of GLONASS as an augmentation to GPS, not as a stand-alone system. Thus, the current number of usable GLONASS satellites and the lack of a full constellation are not critical at this time. This may become an issue if the number of usable satellites drops precipitously and no new launches take place.

Workshop Resolutions and Future Plans for a GLONASS Pilot Service

Gerhard Beutler presented a number of resolutions for a vote at the end of the workshop. Since many of the active participants in the experiment were present at the workshop (along with other individuals who had sufficient interest to pay the registration fee and attend the meeting), the Steering Committee felt that this group should decide (1) whether or not to continue IGEX, and (2) what form this activity should take. The workshop participants voted in favor of all the resolutions with the following results:

1. Global, internationally coordinated GLONASS tracking and orbit determination shall continue in the time interval 1999-2003.
2. The International Association of Geodesy's Committee for the Coordination of Space Techniques for Geodesy and Geodynamics (CSTG) and the International GPS Service (IGS) shall continue to collaborate in an International GLONASS "Pilot Service". This service will be organized according to the rules stated in the memorandum "IGS Policy for the Establishment of IGS Projects and Working Groups" (available through the IGS Central Bureau Information System at < http://igscb.jpl.nasa.gov>).
3. The International GLONASS "Pilot Service" will be proposed as an IGS Pilot Project, initially for the time period 1999-2003.

A new Steering Committee will be formed to (1) prepare a charter for the "Pilot Service", (2) define the duration of the "Pilot Service" as 1999-2003, (3) prepare and send out a new Call For Participation, including a Central Bureau function, and (4) draft an e-mail message that would officially announce the creation of the "Pilot Service". These documents together with a list of Steering Committee members and the proposed relationship between the Pilot Service and the IGS shall be sent to the Chairman of the IGS Governing Board with the request to put the proposal on the agenda of the December 1999 Governing Board meeting. Should the IGS Governing Board decide not to accept the Pilot Service as a pilot project, CSTG has offered to continue the GLONASS operations under its charter. The official Call for Participation will be issued in January 2000. After the resolutions were approved, I was asked to Chair the new Steering Committee, at least on an interim basis, and I have agreed to do so.

The International GLONASS Pilot Service (IGLOPS) will have the following goals and objectives:

1. Establish and maintain a global GLONASS tracking network
    a. Apply IGS network operations standards
    b. Calibrate and evaluate combined GPS/GLONASS receivers and antennas
2. Produce precise (10-cm level) orbits, satellite clock estimates, and station coordinates

a. Evaluate microwave-derived orbits using SLR observations and orbits
b. Incorporate SLR observations in routine orbit processing
c. Obtain initial operational capability of 20-50 cm orbits at Analysis Centers
d. Receive independent orbit/clock/station solutions from Analysis Centers within 3 weeks of observations

3. Monitor and assess GLONASS system performance
4. Investigate the use of GLONASS to improve Earth Orientation Parameters
5. Improve atmospheric products of the IGS
6. Fully integrate GLONASS into IGS products, operations and programs.

The Call for Participation will request recommitment from the existing GLONASS stations that continue to track and will invite new stations to join. Organizations will also be asked to participate as Analysis Centers, Data Centers and a Central Bureau. Requirements for all these activities will be given in the Call for Participation.

If you have any comments or suggestions, I would very much like to hear them.

Jim Slater,
Chair, IGEX-98 Workshop Organizing Committee
and Interim Chair, International GLONASS Pilot Service Steering Committee

Annex 2

International GLONASS Service Call for Participation

Jim Slater

Hello and welcome to the official start of the International GLONASS Service Pilot Project (IGLOS-PP) sponsored by the International GPS Service (IGS). The pilot project is designed as a more formal continuation of the IGEX-98 experiment that ended in 1999. It is the result of recommendations made at the IGEX-98 Workshop in September 1999 in Nashville, Tennessee. This message will announce the new mail service and the official Call for Participation for the IGLOS-PP.

Information about the pilot project can be found on the IGS Central Bureau web site at http://igscb.jpl.nasa.gov/projects/iglos/glonass.html. A copy of the Charter for the new pilot project is available at this site as well as historical information about IGEX-98.

At this time, we are initiating a new mail service called IGLOSMail. This will replace IGEXMail, which has served us well up to now. The new IGLOSMail service is effective immediately and is supported by the IGS Central Bureau at the Jet Propulsion Laboratory in California. All the subscribers to the IGEXMail have been automatically transferred to the new IGLOSMail subscriber list. Please begin using the IGLOSMail today. The archives of the IGEXMail have been transferred to the IGS Central Bureau and can be found on the IGS web site. To send a message to the IGLOS mailing list, email it to: iglosmail@igscb.jpl.nasa.gov. Please ensure the first line of the body of your message starts with the string "Author: " followed by the names of the author(s) of the message. Also, the Subject field of the email should not be blank. IGLOSMail will begin with message number 1. (An example is given at http://igscb.jpl.nasa.gov/faqs.html)

Approximately 25-30 tracking stations and three Analysis Centers have continued to collect GLONASS data and to produce precise orbits on an informal basis since the end of IGEX-98. Currently, ten GLONASS satellites are operational, although many of these are quite old. A new launch of three satellites has been mentioned by Russian authorities perhaps as early as July, but one cannot be certain of these things until they occur. There seems to be sufficient interest in GLONASS as an augmentation to GPS for scientific applications and for other developmental purposes to warrant continued exploitation of the satellites as long as they remain viable. The pilot project committee will reassess the constellation status and the pilot service at six-month intervals to confirm that there is still sufficient benefit and interest in maintaining the operation.

The new Call for Participation in the International GLONASS Service Pilot Project is given below. A copy of the Call for Participation can also be found at the IGS IGLOS-PP page of the web site noted earlier. All interested parties are invited to respond to this Call for Participation. The document describes the project, its goals and objectives and organization, lists the project committee members, defines the requirements for participation as an observing station, data center or analysis center, and provides instructions for sending in a proposal. The deadline for submission of proposals is 7 July 2000. Note that there are some changes in the requirements compared to those of the IGEX-98 campaign.

We are looking forward to this new phase of international cooperation in the use of the GLONASS constellation and hope it continues to be a productive endeavor for all involved.

Jim Slater, Chair
IGLOS Pilot Project Committee

Annex 2

INTERNATIONAL GPS SERVICE
CALL FOR PARTICIPATION
25 May 2000

INTERNATIONAL GLONASS SERVICE - PILOT PROJECT
2000-2003

Prepared by Pilot Project Committee

TABLE OF CONTENTS

1. IGLOS-PP: Description of the Pilot Project

The International GLONASS Service - Pilot Project (IGLOS-PP) is a pilot service of the International GPS Service (IGS) to track and analyze data from the Russian GLONASS satellite constellation. The primary products of the service are dual-frequency observations from the global tracking network and precise orbits computed for each satellite. These are made available to support and encourage other applications and studies. In particular, the products from the Service facilitate the use of combined GLONASS and GPS observations for scientific and engineering applications, and allow users to experiment with the combined systems as a prototype Global Navigation Satellite System. The pilot service will operate for a period of up to four years, from 2000-2003.

1.2. Goals and Objectives

The goals and objectives of the IGLOS Pilot Service are as follows:

1. Establish and maintain a global GLONASS tracking network

a. Collocate dual-frequency, combined GPS/GLONASS receivers with dual-frequency GPS receivers or upgrade existing dual-frequency GPS receivers to dual-frequency, combined GPS/GLONASS receivers at existing IGS sites and at new sites
b. Apply International GPS Service (IGS) network operations standards
c. Calibrate and evaluate combined GPS/GLONASS receivers and antennas

2. Produce precise (10-cm level) orbits, satellite clock estimates, and station coordinates
a. Evaluate microwave-derived orbits using SLR observations and orbits
b. Incorporate SLR observations in routine orbit processing
c. Obtain initial operational capability of 20-50 cm orbits at Analysis Centers

d. Receive independent orbit/clock/station solutions from Analysis Centers within three weeks of observations

3. Monitor and assess GLONASS system performance

4. Investigate the use of GLONASS to improve Earth Orientation Parameters

5. Improve atmospheric products of the IGS

6. Fully integrate GLONASS into IGS products, operations and programs.

1.3. Organizational Aspects

The Pilot Service will utilize the existing infrastructure of the IGS as much as possible without disrupting activities supporting GPS data collection and processing. It will take advantage of the operational experience gained from the International GLONASS Experiment (IGEX-98) carried out in 1998-99. The Call for Participation is being issued to officially enlist the participation of current IGS network stations, analysis centers, and data centers, as well as to solicit the participation of new stations, analysis centers, and data centers. The IGS Central Bureau will take responsibility for including the pilot service within the IGS operations. The pilot service will include SLR stations, GLONASS stations, and combined GPS/GLONASS stations that meet IGS network requirements and additional GLONASS-specific requirements.

1.4. Project Committee

An IGLOS Pilot Project Committee is responsible for establishing and managing the service during the pilot period. The members are:

Vladimir Glotov, Mission Control Centre, Russian Space Agency
Ramesh Govind, Australian Surveying and Land Information Group
Werner Gurtner, University of Berne, Astronomical Institute, ILRS Liaison
Arne Jungstand, EC Joint Research Centre, Space Applications Institute, and DLR
Angelyn Moore, IGS Central Bureau
Ruth Neilan, IGS Central Bureau, Director (ex officio)
Carey Noll, NASA Goddard Space Flight Center, Data Center Coordinator
James Slater, National Imagery and Mapping Agency, Chair
Tim Springer, University of Berne, IGS Analysis Center Coordinator (ex officio)
Robert Weber, University of Technology, Vienna, GLONASS Analysis Center Coordinator
Pascal Willis, Institut Geographique National.

The IGLOS Pilot Project Committee will review and approve proposals for establishment of new stations, analysis centers, and data centers, taking appropriate actions as necessary. The description and responsibilities of these fundamental IGS components are located in the IGS Terms of Reference at <<http://igscb.jpl.nasa.gov/organization/bylaws.html>>. Technical specifications for stations, analysis centers and data centers are included in this Call for Participation. The Committee will develop operational guidelines for incorporating the GLONASS operations into the IGS. Liaisons are maintained with the International Laser Ranging Service, the International Association of Geodesy, and the GLONASS Coordination Scientific Information Center of the Russian Federation Ministry of Defense as appropriate.

2. Call for Participation

The IGLOS Pilot Project Committee is seeking participants in the International GLONASS Service Pilot Project in the following categories:

- IGLOS Observing Stations
- IGLOS Data Centers
- IGLOS Analysis Centers
- IGLOS Associate Analysis Centers

2.1. IGLOS Observing Stations

This call goes to individual stations willing to operate combined GPS/GLONASS receivers and to "Operational Centers" currently in charge and control of several IGS stations as part of a special-purpose or local permanent GPS or GLONASS network.

2.1.1. Receivers

Only geodetic-type receivers (capable of collecting pseudorange and carrier phase observations) may be used in IGLOS. Receivers must be able to track at least four GPS and four GLONASS satellites simultaneously.

Receivers should be able to track the satellites of both systems on both frequencies. For special purposes, as for example, time transfer experiments, receivers with lower performance might be proposed, too.

One of the goals of IGLOS is the total incorporation of the high-end dual-system receivers into the IGS network. Such GPS/GLONASS receivers should either be collocated on IGS sites (with the expectation of eventually replacing the GPS receiver) or on sites complementing the existing IGS network.

The local ties between the antennae of existing IGS receivers, ILRS systems and the collocated dual-system receivers should be known with an accuracy of about 1 mm (in ITRF).

A GPS/GLONASS Site Information Report must be submitted to the IGS Central Bureau prior to the start of the pilot project (available at the IGS Central Bureau Information System (see ftp://igscb.jpl.nasa.gov/igscb/resource/blank.log).

If the dual-system receiver is driven by an accurate external clock (rubidium, cesium or hydrogen standard), this information should be included in the proposal and the site log.

2.1.2. Operational considerations

The sites participating in the IGLOS Pilot Project will have to observe the same guidelines and rules as the official IGS sites. Guidelines and checklists can be found at http:/igscb.jpl.nasa.gov/network/guide_igs.html and http:/igscb.jpl.nasa.gov/network/join_igs.html.

Observing stations are requested to forward their data to an IGS data center within 2 hours from the end of the UT day on which the data were collected. Currently, many sites of the IGS and other permanent networks are upgrading their data submission procedures to enable hourly uploads. We encourage IGLOS stations to use hourly data collection and upload, if possible.

The exchange file format is the RINEX format (see ftp://igscb.jpl.nasa.gov/igscb/data/format/rinex210.txt).

The following naming conventions will be followed:

A 4-character acronym for each receiver operated as part of the pilot service should be proposed to and approved by the IGS Central Bureau (igscb@igscb.jpl.nasa.gov).

For each marker, a DOMES number (a globally unambiguous marker number used by ITRF) has to be requested from the ITRF Section of the IERS Central Bureau (see http://lareg.ensg.ign.fr/ITRF/domesreq.html, e-mail contact: domes@ensg.ign.fr).

The following file naming convention will be observed (see also recommendation in the RINEX 2.10 documentation ftp://igscb.jpl.nasa.gov/igscb/data/format/rinex210.txt):

----------Compressed File----------				
File Type	ASCII File	UNIX	VMS	DOS
Observation	ssssdddf.yyO	ssssdddf.yyD.Z	ssssdddf.yyD_Z	ssssdddf.yyE
GPS Navigation	ssssdddf.yyN	ssssdddf.yyN.Z	ssssdddf.yyN_Z	ssssdddf.yyX
GLONASS Navigation	ssssdddf.yyG	ssssdddf.yyG.Z	ssssdddf.yyG_Z	ssssdddf.yyV
Met Data	ssssdddf.yyM	ssssdddf.yyM.Z	ssssdddf.yyM_Z	ssssdddf.yyW

ssss: 4-character station code
ddd : day of the first record
yy : year of the first record
f : file sequence number within the day
(0: containing all data of the day)
Hourly files use 'a' for 00:00:00 - 00:59:30 UT
'b' for 01:00:00 - 01:59:30 UT
.
.
'x' for 23:00:00 - 23:59:30 UT

The extension yyD (or yyE in DOS) indicates Hatanaka-compressed files.

2.1.3. Local Geodetic Ties

The local geodetic ties between the GLONASS equipment and all geodetic equipment in the vicinity (GPS, DORIS, SLR, VLBI, PRARE,..) must be performed, documented in the site log and made available before the start of the Pilot Project. The ties have to be reported as Cartesian coordinate differences (delta X/Y/Z) parallel enough to the Earth-centered ITRS to maintain the accuracy of a few millimeters.

2.2. IGLOS Data Centers

One of the final goals of IGLOS is the total incorporation of the GLONASS data into the IGS data flow.

Therefore we ask the existing IGS Data Centers (Global, Regional, Local) to confirm their intentions to extend their activities to the handling of the GLONASS data following the IGS guidelines with necessary adjustments according to decisions to be taken by the IGLOS-PP Committee and the IGS Central Bureau.

The proposal should describe the maximum number of additional stations from which data can be received, stored and made available for anonymous ftp access.

2.3. IGLOS Analysis Centers

Analysis Centers will process tracking data of the IGLOS-PP network in order to calculate and make available products which facilitate the use of combined GPS and GLONASS observations for scientific and engineering applications. Initially, the list of products should cover

a. precise satellite orbits
   (initial operational capability 20-50cm /10-cm level in the long run)
b. satellite clock estimates
c. station coordinates.

Two types of Analysis Centers are defined in this Call for Participation:

* Type 1 IGLOS Analysis Centers should produce orbit, clock, and station solutions in the same time frame as the IGS Analysis Centers.

* Type 2 IGLOS Analysis Centers should produce orbit, clock, and station solutions within 3 weeks of observations (with the goal of approaching the time frame of Type 1 IGLOS Analysis Centers within the period of operation of IGLOS-PP).

Moreover, IGLOS Analysis Centers are encouraged to study in detail the enhanced potential of combined GPS/GLONASS data for improving the quality of their Earth rotation parameters and atmospheric monitoring products as well as the impact of incorporation of SLR observations in the routine processing.

Data Analysis has to follow as far as possible recommendations given in the IERS Standards. The full integration of GLONASS into IGS products, operations and programs is an important goal of this Pilot Project.

2.4. IGLOS Associate Analysis Centers

In the IGLOS Pilot Project, we are seeking groups to perform independent routine analyses and evaluations of orbits, clocks, receivers, baselines, regional networks or other entities including specifically:

a. Comparison of results (obtained by the various Analysis Centers) similar to those routinely performed by the IGS and IGLOS Analysis Coordinators

b. Evaluations based on independent techniques, e.g., SLR observations.

Proposals from SLR Analysis Centers and other analysis groups are encouraged.

3. Instructions for Submitting Proposals

Proposals submitted in response to the Call for Participation should contain:

- the completed proposal form signed by an authorized official representative of the organization

- a detailed plan describing the activities proposed by the organization

Send proposals to:

iglos-proposals@igscb.jpl.nasa.gov (ASCII preferred)

and

Ruth Neilan
Director, IGS Central Bureau
Jet Propulsion Laboratory MS 238-540
4800 Oak Grove Drive
Pasadena, CA 91109, U.S.A.

For proposals submitted by e-mail, please send a copy of the completed proposal form with the original signature page by regular mail.

Questions can be sent to:

Jim Slater
National Imagery and Mapping Agency
Mail Stop D-68
4600 Sangamore Rd.
Bethesda, MD 20816-5003, U.S.A.

Phone: 301-227-4549
Fax: 301-227-4749
E-mail: slaterj@nima.mil

Annex 2

4. Proposal Form

PROPOSAL SUBMITTED IN RESPONSE TO THE CALL FOR PARTICIPATION - INTERNATIONAL GLONASS SERVICE PILOT PROJECT (IGLOS-PP)

Proposing Organization:

Point of Contact:

Name:

Address:

Telephone:
FAX:
E-mail:

Authorizing Official:

Name:

Address:

Telephone:
FAX:
E-mail:

Signature:

Proposal for:

IGLOS Observing Station

IGLOS Data Center

IGLOS Analysis Center

IGLOS Associate Analysis Center

For Joint proposals:

Collaborating institutions:

Contacts:

Detailed Proposal: