THE IGLOS PILOT PROJECT - TRANSITIONING AN EXPERIMENT INTO AN OPERATIONAL SERVICE

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OUTLINE OF PRESENTATION

- Motivation for Initial Experiment
- International GLONASS Experiment (IGEX-98)
  - Objectives
  - Accomplishments
- Key Elements for Integrating GLONASS into IGS
- International GLONASS Service Pilot Project (IGLOS)
  - Goals and Objectives
  - GLONASS Constellation
  - Station Network
  - Data Products
  - Product Usage
- Summary and Conclusions
MOTIVATION FOR IGEX-98

- GLONASS already existed
- GLONASS comparable to GPS so relatively “easy” to assimilate into existing processing
- Significant augmentation to GPS alone
- Dual-frequency P-code
- Added geometric strength
- Receiver technology available
- Scientific and navigation communities interested in exploiting system
- Uncertain future (now or never)
IGEX-98 OBJECTIVES

- Collect globally-distributed GLONASS data set over long time period, using dual-frequency receivers collocated with GPS receivers at known ITRF locations.
- Compute precise orbits (1 m or better)
- Evaluate receivers
- Develop data processing software
- Compare PZ-90, WGS-84 and ITRF reference frames
- Facilitate timing and time transfer
- Stimulate other scientific applications.
IGEX-98 CAMPAIGN STATISTICS

- 19 October 1998 – 19 April 1999
- 13-14 GLONASS satellites
- 61 GLONASS receiver tracking sites
- 68 receivers deployed
- 26 countries
- 30 SLR stations in 15 countries
- 6 regional data centers
- 2 global data centers
IGEX-98 ACCOMPLISHMENTS

- First global tracking network for GLONASS
- First extensive use of geodetic-quality, dual-GNSS receivers capable of tracking all satellites in view
- First precise GLONASS orbits
  - 11 Analysis Centers generated orbits
  - Orbit solutions consistent at 20-30 cm level
- Development of prototype data processing software and procedures for processing GPS and GLONASS data
- 5 independent determinations of PZ-90 to WGS-84/ITRF transformation
KEY ELEMENTS REQUIRED FOR INTEGRATING GLONASS INTO IGS OPERATIONS

- GPS knowledge base
- Receiver hardware and software
- Common geodetic reference frame
- Common time standard
- Standardized data formats
- Data communications and data distribution infrastructure
- Global tracking network
- Data processing software
- Analysis Centers
THE IGS GLONASS PILOT PROJECT

- Officially started February 2000
- Goals and Objectives:
  - Establish and maintain global GLONASS tracking network
  - Produce precise (10-cm level) orbits, satellite clock estimates and station coordinates
  - Monitor and assess GLONASS system performance
  - Investigate use of GLONASS to improve Earth orientation parameters
  - Improve IGS atmospheric products
  - Fully integrate GLONASS into IGS products, operations and programs.
- Requirements:
  - Use only dual-frequency GLONASS receivers
  - Apply IGS network operations standards
  - Include SLR orbits in combination orbit product
  - Obtain independent orbit, clock and station solutions from Analysis Centers within 3 weeks of observations
  - Calibrate GPS/GLONASS receivers and antennas.
IGLOS OPERATIONS –
GLONASS CONSTELLATION

- Annual launches of new satellites in 2000-2003
- 10 operational satellites as of 25 February 2004
- Only 2 of 3 orbit planes populated
- Provide significant contribution to satellite visibility as addition to GPS constellation

Examples:
- Thule, Greenland (76°N)
- Capoterra, Italy (39°N)
- Kourou, French Guyana (5°N)
- Mattersburg, Austria (47°N)
GLONASS AND GPS SATELLITE VISIBILITY AND GDOP
THULE, GREENLAND (76°N)

Almanac Date: 17 Feb 04  Observation Date: 20 Feb 04  Elevation Cutoff: 5°
GLONASS AND GPS SATELLITE VISIBILITY AND GDOP

CAPOTERRA, ITALY (39ºN)

Almanac Date: 17 Feb 04     Observation Date: 20 Feb 04     Elevation Cutoff: 5º
GLONASS AND GPS SATELLITE VISIBILITY AND GDOP
KOUROU, FRENCH GUYANA (5ºN)

Almanac Date: 17 Feb 04     Observation Date: 20 Feb 04     Elevation Cutoff: 5º
GLONASS AND GPS SATELLITE VISIBILITY AND GDOP
MATTERSBURG, AUSTRIA (47°N)

Almanac Date: 17 Feb 04     Observation Date: 20 Feb 04
## IGLOS DATA PRODUCTS

<table>
<thead>
<tr>
<th>Analysis Center</th>
<th>Products</th>
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<tbody>
<tr>
<td>BKG</td>
<td>Daily orbits</td>
</tr>
<tr>
<td>CODE</td>
<td>Daily orbits, Rapid orbits</td>
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<tr>
<td></td>
<td>Ionosphere, Troposphere</td>
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<tr>
<td></td>
<td>Earth orientation parameters, Station coords.</td>
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<tr>
<td>ESA</td>
<td>Daily orbits, Satellite clock estimates</td>
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<tr>
<td></td>
<td>Station coords.</td>
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<tr>
<td>MCC</td>
<td>Weekly orbits</td>
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IGLOS ANALYSIS CENTER ORBITS
DELAY IN SUBMISSION (OCT 98 – Feb 04)
### GLONASS LONG ARC (7 DAYS) SOLUTION RMS
GPS Week 1253

(RMS values in cm)

<table>
<thead>
<tr>
<th>Satellite</th>
<th>BKG</th>
<th>CODE</th>
<th>ESA</th>
<th>MCC</th>
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<td>5</td>
<td>8</td>
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<tr>
<td>Slot 24/Plane 3</td>
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</tbody>
</table>
GLONASS SLOT 3 LONG ARC (7 DAYS) SOLUTION
GPS Week 1253 – RADIAL COMPONENT

Glonass Slot 3 / Radial Component wrt. to CODE orbit

Days in GPS Week 1253

meter
GLONASS SLOT 3 LONG ARC (7 DAYS) SOLUTION
GPS Week 1253 – ALONG-TRACK COMPONENT

Glonass Slot 3 / Along Track Component wrt. CODE orbit

Days in GPS Week 1253

Meter

BKG
ESA
MCC
GLONASS SLOT 3 LONG ARC (7 DAYS) SOLUTION
GPS Week 1253 – CROSS-TRACK COMPONENT

Glonass Slot 3 / Across Track Component wrt. CODE ort

Days in GPS Week 1253

Meter

BKG  MCC  ESA
IGLOS PRODUCT USAGE

- GLONASS observations imbedded with GPS in RINEX files – impossible to tell how many “GLONASS” users
- Products available at NASA CDDIS Global Data Center
  - Users from 21 countries in 2003
  - Russia – biggest user (no. of downloaded files)
  - British government – 2nd biggest user
SUMMARY AND CONCLUSIONS

- IGEX-98 was proof-of-concept
- IGLOS Pilot Project – operational implementation of concept
- Demonstrated integrated operation of 2 GNSS’s in single operational framework
- Process was aided by similarity of the two systems
- Required –
  - Retooling GPS data processing software at IGS Analysis Centers
  - Minor modifications to GPS data formats
  - Application of IGS standards to incorporation of GLONASS receivers and data in tracking network and at Data Centers
- Standardization of data formats, tracking stations, communications protocols and data management critical to success of project
SUMMARY AND CONCLUSIONS (Cont’d)

- Receiver manufacturers produced geodetic-quality equipment and firmware that tracked 2 constellations simultaneously, output data relative to a single time reference and in a standard format.
- IGLOS tracking network has been very stable
  - Now consists exclusively of Ashtech and Javad receivers.
- Reference frame compatibility issue solved by tying stations to ITRF (thru GPS).
- Undifferenced observables rather than double-differences may be preferable for cases where satellites are sparse due to constellation build-up or depletion.
SOME REMAINING ISSUES

- Global network is uneven – overconcentration in Europe, no stations in Africa, few stations in N. and S. America and Asia
- Broadcast orbits still in PZ-90 - would be more useful if based on global realization of ITRF
- Receiver antenna calibrations needed for GLONASS frequencies
- Impact of additional satellites –
  - 10 GLONASS satellites measurably improve satellite visibility in combination with GPS
  - Benefit to IGS products, but extra burden for network operations, Analysis Centers and Data Centers
  - Data management problem to ensure throughput, archiving and retrieval capabilities keep up with data volume
THE NET RESULT....

- Key objectives of IGLOS have been met
- Uncertainty still exists about long-term viability of GLONASS
- Lessons learned from IGLOS will make road to Galileo a little smoother.