SPACE GEODESY PROGRAM

The Techniques

Past:
- Mini-Track
- Doppler

Present:
- SLR
- LLR
- VLBI
- GPS
- GLONASS
- DORIS
- PRARE

Future:
- Interferometric SAR
- GPS Arrays (Ground, Space
- Laser Altimetry
- Seafloor Geodesy

Its Science Contributions

- Earthquake Processes
- Ocean Circulation
- Atmospheric Circulation
- Sea Level
- Plate Tectonics
- Lithosphere Processes
- Gravity
- Land and Ice Topography
- Post-Glacial Rebound
- Ocean Tides
- Atmospheric Tides
- Solid Earth Tides
- Core Dynamics
- General Relativity
- Fundamental Physics
- Astrophysics

The U.S. Involvement

- NASA
- NOAA
- USGS
- USNO
- NIMA
- NSF
- USAF
- NRL
- Many Major Universities Institutes

The Foreign Involvement

- Over 80 Countries
- Cooperative Operations
- Shared Data
- Joint Campaigns
- Joint Technology Development Programs

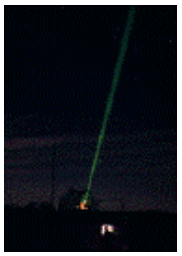
SPACE TECHNIQUES

GPS

Global Positioning System

Source: Military satellites equipped with precise clocks transmitting satellite messages such as ephemeris, clock offsets, etc.
Instrument: Dual frequency GPS receiver and antenna
Observable: Station to satellite pseudorange, phase delay
Yield:
1. Precise satellite ephemerides
2. Relative positions of and distances between observing stations
3. Earth rotation, orientation, polar motion, etc.

SLR



Satellite Laser Ranging

Target: Satellite equipped with corner cubes
Instrument: Ground-based short-pulse laser transmitter
Observable: Round-trip pulse time-of-flight to satellite
Yield:
1. Satellite orbit
2. Positions of and distance between observing stations
3. Earth rotation, orientation, polar motion, etc.

VLBI

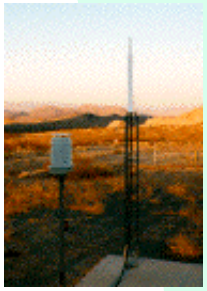
Very Long Baseline Interferometry

Source: Quasar (microwave frequencies)
Instrument: Radio telescope equipped with X- and S-wideband receivers
Observable: Difference in signal arrival times
Yield:
1. Correlated delay and delay rate of simultaneous observations as a function of time
2. Distance between and positions of observing stations
3. Earth rotation, orientation, polar motion, etc.

SPACE TECHNIQUES
(continued)

DORIS

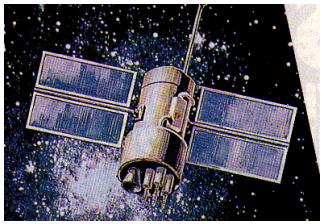
Doppler Orbitography and Radiolocation Integrated by Satellite



Target: Satellites equipped with DORIS receiver and uplink hardware
Instrument: Beacon transmitting radiofrequency signals
Observable: Doppler shift on radiofrequency signals
Yield:
1. Precise satellite ephemerides
2. Positions of observing stations
3. Earth rotation

GLONASS

GLObal NAvigation Satellite System



Source: Russian military satellites equipped with precise clocks transmitting satellite messages such as ephemeris, clock offsets, etc.
Instrument: GLONASS receiver and antenna
Observable: Station to satellite pseudorange, phase delay
Yield:
1. Precise satellite ephemerides
2. Relative positions of and distances between observing stations
3. Earth rotation, orientation, polar motion, etc.

CRUSTAL DYNAMICS DATA INFORMATION SYSTEM (CDDIS)

- The CDDIS was established in 1982 as a dedicated data bank to archive and distribute all Crustal Dynamics Project-acquired data and information about these data
- CDDIS continues to serve as the archive and distribution center for space geodesy data, particularly GPS, laser, DORIS, and VLBI data
- 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 globally-distributed sites daily
- CDDIS also serves as a data center for GPS and DORIS in support of the International Earth Rotation Service (IERS)
- CDDIS provides on-line archive of TOPEX/Poseidon (SLR and DORIS) and ERS-2 (SLR) data for near real-time access by POD analysis centers
- Selected data sets are accessible to scientists through ftp and WWW; general information about all data are accessible via WWW

CDDIS INTRODUCTION
(Continued)

- Use of the ORACLE data base management system (DBMS) provides flexibility for storing and accessing diverse data sets
- On-line archive consists of ORACLE data base and GPS, SLR, VLBI, and DORIS data sets (over 100 Gbytes on-line, many Gbytes near-line); off-line archive consists of GPS, SLR, DORIS, and VLBI magneto-optical disks and magnetic tapes
- CDDIS currently operational on dedicated DEC AlphaServer 4000 running UNIX; archive of data to CD-ROM for accessibilty through jukebox underway
- CDDIS issues bimonthly bulletin and organizes and generates space geodesy site catalogue and personnel directory
- FTP: cddisa.gsfc.nasa.gov
  WWW: http://cddisa.gsfc.nasa.gov/cddis_welcome.html
  email: noll@cddis.gsfc.nasa.gov
  dube@cddis.gsfc.nasa.gov

RECENT DEVELOPMENTS

- DEC AlphaServer 4000 was purchased in 1997 and became operational July 1, 1998
- CDDIS selected to serve as a Global Data Center for the International GLONASS Experiment (IGEX'98), a test service similar to IGS
- CDDIS also selected to serve as Global Data Center for both the International Laser Ranging Service (ILRS) and the International VLBI Service (IVS)
- Started migration of GPS data archive from magneto-optical disks to CD-ROM
- One year of GPS data available on-line; all IGS products (since June 1992) are on-line
- All SLR (1976-present), DORIS (1992-present), VLBI (1979-present) data holdings currently on-line
- VAX computer (cddis.gsfc.nasa.gov) utilized for tape migration, email, etc.

CDDIS ARCHIVE CONTENTS

- GPS
  - Temporal coverage: 1990 through present
  - Data volume: On-line: 50 Gbytes + 300 Gbyte jukebox; Off-line: 500 Gbytes
- GLONASS
  - Temporal coverage: 1998 through present
  - Data volume: On-line: 5 Gbytes; Off-line: n/a
- SLR
  - Temporal coverage: 1976 through present
  - Data volume: On-line: 5 Gbytes; Off-line: 200 Gbytes
- VLBI
  - Temporal coverage: 1979 through present
  - Data volume: On-line: 18 Gbytes; Off-line: 100 Gbytes
- DORIS
  - Temporal coverage: 1992 through present
  - Data volume: On-line: 5 Gbytes; Off-line: 100 Gbytes

CDDIS HARDWARE CONFIGURATION

- Components
  - DEC AlphaServer 4000
  - 512 Mbytes memory
  - ~210 Gbytes on-line magnetic disk space
    - ~100 Gbytes for GPS data and products
      - GLONASS, SLR, VLBI, DORIS data also on-line
  - Digital UNIX
  - 600 slot CD-ROM JVC jukebox

- Host name cddisa.gsfc.nasa.gov (128.183.204.168)

INTRODUCTION TO THE IGS

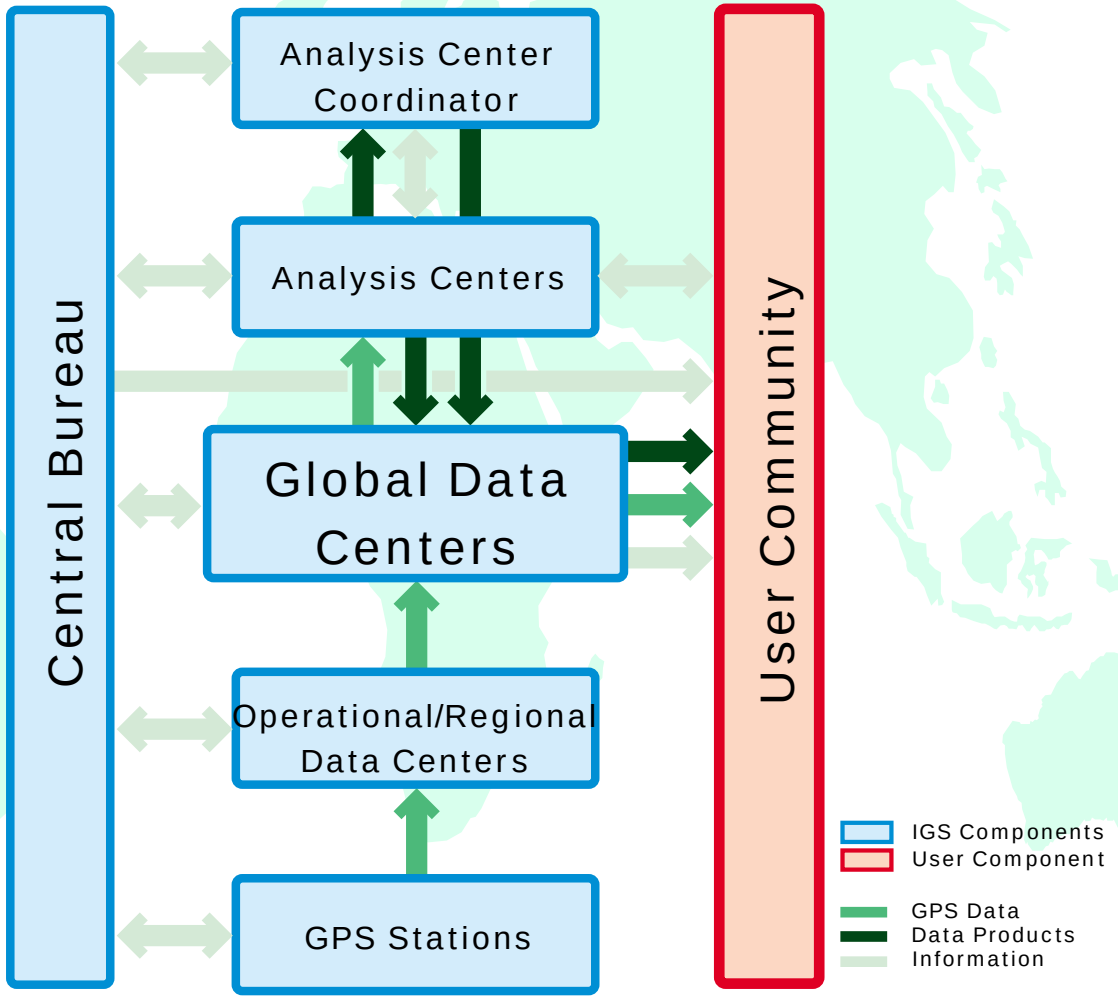
- The main mission of the International GPS Service (IGS) is to provide a service to support geodetic and geophysical research activities through GPS data and data products
- The IGS has been an operational service since 1994 (test service since 1992)
- The IGS provides near real-time access to GPS data from a global network of sites
- The current network consists of nearly 200 globally distributed sites
- The GPS data sets are used by the IGS to generate products on a routine basis
- Over 80 global institutions and organizations contribute to the IGS activities
- The distributed nature of the IGS data flow is an efficient method for providing near real-time data availability to global community
- The IGS is an approved service of the International Association of Geodesy (IAG) and is also a member of the Federation of Astronomical and Geophysical Data Analysis Services (FAGS)

IGS SITE MAP

COMPONENTS OF THE IGS

- Network of global tracking stations
- Data Centers
  - Operational data centers download data from tracking stations
  - Regional data centers provide access to data from a geographic region
  - Global data centers provide access to data and products to IGS and user community
- Analysis Centers and Associate Analysis Centers
  - Analyze GPS data on an operational basis
  - Produce IGS products
- Analysis Center Coordinator
  - Generates combined, official IGS products
- Central Bureau
  - General management of the IGS
- Governing Board

FLOW OF IGS DATA, PRODUCTS, AND INFORMATION



IGS STATIONS AND DATA

- IGS Tracking Stations:
  - Permanently occupied
  - Continuously tracking
  - Equipped with high-precision dual-frequency P-code receiver
  - Operate at 30-second sampling rate
  - Linked electronically for download of data on a timely basis
  - Ideally, single day's worth of data forwarded to data center within 1-2 hours after end of UTC day
  - Subset of sites provide hourly data within 15 minutes
- IGS Data:
  - Daily files containing range observation and broadcast ephemerides
  - Meteorological data from a few sites
  - RINEX format at data centers
  - Files available in compressed (UNIX compression) format at data centers; further compaction used for internal data transmissions
  - Approximately 0.6 Mbytes/site/day (RINEX, compressed)

NEW GPS DATA SETS

- Hatanaka compression (yyd.Z files)
- CDDIS continues to provide access to compressed RINEX observation files (yyo.Z)
- Daily GPS data subdirectories:
  - Daily status file
  - O (RINEX observation data)
  - D (RINEX observation data, Hatanaka compression)
  - M (RINEX meteorological data)
  - N (RINEX broadcast ephemeris data)
  - S (output from teqc)
- Near real-time GPS data
  - Hourly files, 15 minute delay
  - 31 stations
  - Retained for three days
  - Since mid 1998

IGS DATA PRODUCTS

- Seven IGS analysis centers and nine associate analysis centers generate IGS products on a routine basis
- IGS products now available
  - Combined IGS orbit (10 day delay; approaching 5 cm accuracy)
  - Combined IGS ERP (pole 0.2-0.7 milliarcsecond, LOD 50 microseconds/day accuracy)
  - Rapid orbits (17 hour delay; 10 cm accuracy)
  - Predicted orbits (1 hour prior to observation day; 50 cm accuracy)
  - Global annual station position solutions (3 mm to 1 cm accuracy)
- IGS products mainly used for geodetic studies, e.g., plate tectonics, earthquake displacements, Earth orientation, etc.

IGS DATA PRODUCTS
(Continued)

- Recent IGS products include atmosphere measurements to aid in weather forecasting, etc.
- IGS network consists of globally distributed continuously operating stations with dual-frequency P-code receivers
- By using these two frequencies, the effects of the ionosphere can be determined and used to correct positional measurements
- Global ionosphere maps of total electron content (TEC) produced since June 1998
  - Could aid in calibration of altimeter data
  - Correct single frequency GPS data
  - Daily files from five Analysis Centers
- The GPS signal is sensitive to the refractive index of the atmosphere, which is a function of pressure, temperature, and moisture
- Troposphere product currently consists of combined zenith path delay (ZPD); weekly files from IGS sites available since January 1997
- In future, could convert to precipitable water vapor once improved meteorological sensors available at GPS sites

IGS -- BENEFITS TO USERS

- Open access to all IGS data and data products
- High quality GPS data
  - Global network
  - Common, receiver-independent format (RINEX)
  - Continuously available in a timely fashion
  - Interpolation to “higher” sampling rate can be achieved through software
- GPS ephemerides
  - More accurate than broadcast orbits by at least an order of magnitude
- GPS site positions
  - IGS site positions precisely-determined
  - User data can be tied to global reference frame
- Ties to regional networks
  - CORS, SCIGN
  - Other countries

IGEX-98 CAMPAIGN

- Sponsored by IAG Commission VIII (CSTG), IGS, ION, and IERS
- Main objectives:
  - Set up a GLONASS observation network
  - Test GLONASS data processing s/w
  - Determine GLONASS orbits of at least meter-quality
  - Connect GPS and GLONASS time systems
  - Compare receiver equipment performance
  - Others
- Campaign runs from Oct. 19, 1998 through January 22, 1999
- Nearly 100 GLONASS, GPS/GLONASS and GPS receivers proposed; currently over 50 are operational
- IGEX infrastructure modeled after IGS
- To IGS Global Data Centers (CDDIS and IGN) are also GDCs for IGEX
- For more information see IGEX'98 web site: http://lareg.ensg.ign.fr/IGEX

IGEX DATA AND PRODUCTS

- GLONASS Data:
  - Daily files (00:00:00 and 23:59:30 GPS time)
  - 30-second sampling rate
  - Observation, GPS and GLONASS navigation, and optional meteorological data
  - RINEX format (Hatanaka and UNIX compression)
  - Data from receiver to global data center within 48 hours
- IGEX Products:
  - Precise daily or weekly GLONASS ephemerides in SP3 format
  - Satellite clock information
  - Earth rotation parameters
  - Station coordinates in SINEX format

IGEX-98 SITE MAP

INTERNATIONAL LASER RANGING SERVICE (ILRS)

- The International Laser Ranging Service (ILRS) provides global satellite and lunar laser ranging data and their related products to support:
  - Geodetic and geophysical research activities
  - Precise orbit determination for altimetry satellites (ERS, TOPEX, etc.)
  - IGEX-98 campaign (all GLONASS satellites are equipped with retroreflectors)
- ILRS has been an operational service as of November 1998
- Components of the ILRS:
  - Network of laser tracking sites
  - Data centers
  - Analysis centers
  - Central bureau
  - Working groups
  - Governing board

ILRS DATA AND PRODUCTS

- ILRS Data:
  - Daily files containing on-site normal points, sorted by satellite in CSTG format
  - Daily and monthly full-rate data files from a subset of the global network in MERIT-II format
  - Currently, over 30 satellites and four sites on the moon are tracked on a routine basis
  - Approximately 1 Mbyte/day on-site normal point data (uncompressed); 2 Mbytes/day full-rate data (compressed)
- ILRS Products:
  - Precise satellite ephemerides
  - Site positions and velocities
  - Utilized for maintaining the International Terrestrial Reference Frame (ITRF)
  - Earth rotation parameters

ILRS SITE MAP

FUTURE PLANS

- Make most on-line data holdings accessible through anonymous ftp (currently SLR and GLONASS data)
- Continue migration of older GPS data to CD-ROM
- Purchase additional disk space
- Implement data validation routines and check historical GPS data archive
- Investigate common directory structure among IGS data centers
- Support low-Earth orbiter (LEO) missions:
  - GPS data at higher sampling rate (1 second) for a subset of the IGS network
  - Near real-time data transmission
  - Archive of on-board GPS receiver data