



NASA's Archive of Space Geodesy Data

# CDDIS Data Discovery

Carey Noll

CDDIS Manager/Code 690.1

- Background
- Data description
- User description
- Discovery desirables

# Why are we here??

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- To provide advice on methods to develop a search/metadata interface tool for CDDIS to:
  - Aid users in discovery of CDDIS data, products, and information
  - Aid staff in archive management
  - Promote CDDIS data holdings to a larger community (e.g., through metadata standards)

# CDDIS Overview

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- Crustal Dynamics Data Information System
- NASA's active archive of space geodesy data, products, and information
- CDDIS funded by NASA (through ESDIS) but cooperates extensively with the international community
- Majority of CDDIS archive utilized for geodetic studies, e.g., plate tectonics, earthquake displacements, Earth orientation, etc.
- Plays an interdisciplinary role in supporting derivation of the ITRF, POD for NASA/international missions, atmospheric studies, etc.

# Space Geodesy (1/2)

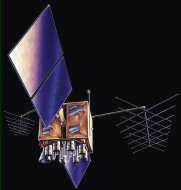
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- Data
  - GNSS: 417 sites tracking GPS, GLONASS
  - Laser Ranging (SLR and LLR): 42 sites tracking 35+ satellites
  - VLBI: 45 sites
  - DORIS: 58 sites tracking 6 satellites
- Products
  - Precise network station positions (for ITRF)
  - Satellite orbits (for POD)
  - Station and satellite clocks (for timing)
  - Earth rotation parameters
  - Positions of celestial objects (for CRF)
  - Atmospheric parameters (Ionosphere TEC, Troposphere ZPD)
  - ...

# Space Geodesy (2/2)

- Stations in the GNSS, SLR/LLR, VLBI, and DORIS networks generate point data on a multi-day, daily, hourly, and/or sub-hourly basis
- File size is typically <2Mb/data “granule”, <10Mb/derived product “granule”

GNSS: Satellites (GPS-U.S., Russia-GLONASS, future EU-Galileo) equipped with precise clocks transmitting messages such as ephemeris, clock offsets, etc. to ground (and spaced-based) receivers to measure station to satellite pseudorange, phase delay



SLR/LLR: Ground-based short-pulse laser transmitting to satellites (or planetary targets) equipped with corner cubes to measure round-trip pulse time-of-flight to satellite



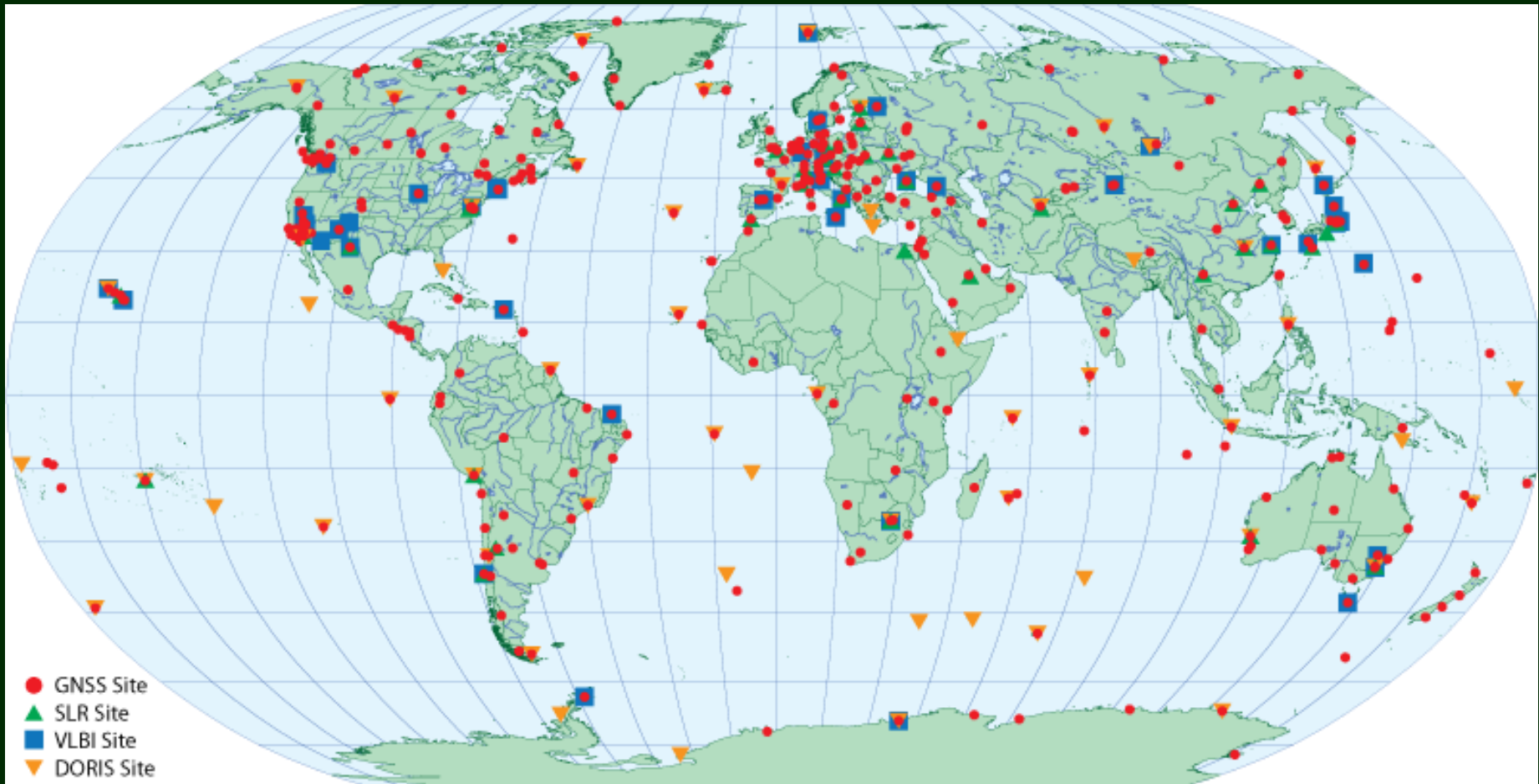
VLBI: Radio telescopes equipped with X/S wideband receivers record signals from quasars to measure difference in signal arrival times



DORIS: Satellites equipped with DORIS receiver and uplink hardware transmit signals to ground beacons to measure Doppler shift on radiofrequency signals



# CDDIS Data: Global Networks



# IAG Services

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- Services function as cooperating federations dedicated to a particular type of data
- Provide data and products on an operational basis to geodesy analysts as well as a broader scientific community
- Examples of a successful model of community management:
  - develop standards
  - self-regulating
  - monitor performance
  - define and deliver products using pre-determined schedules
- Successful operation through cooperation of many international organizations who leverage their respective limited resources to all levels of service functionality

# CDDIS Support of IAG Services

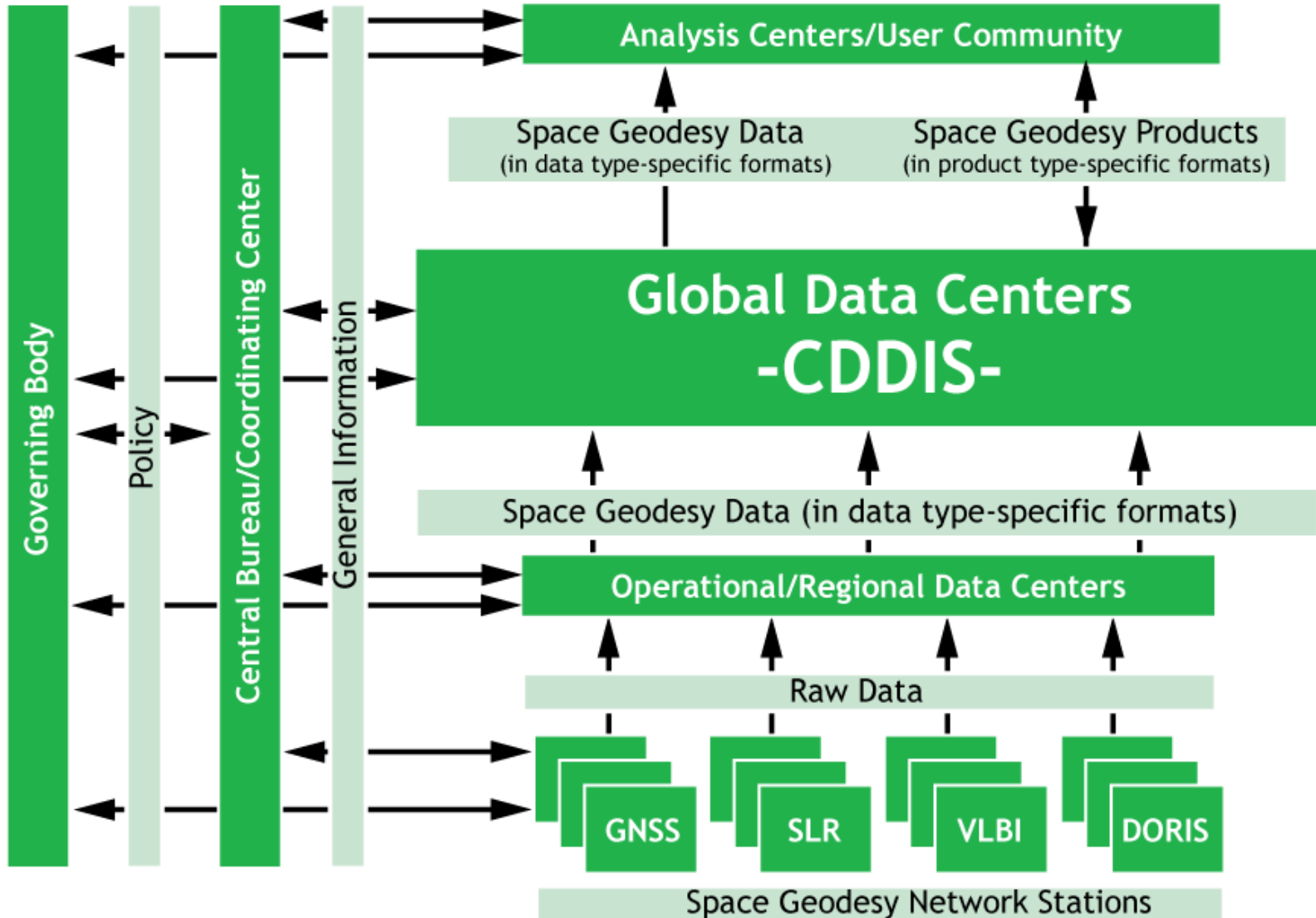
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- CDDIS is the principle data center supporting services created under the International Association of Geodesy (IAG):
  - International GNSS Service (IGS)
  - International Laser Ranging Service (ILRS)
  - International VLBI Service for Geodesy and Astrometry (IVS)
  - International DORIS Service (IDS)
  - International Earth Rotation and Reference Frame Service (IERS)
- Provides infrastructure for populating CDDIS archive
- Primary user base for CDDIS archive



# Flow of Files to/from CDDIS

(Information, Data, Products)



# CDDIS Archive

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- Archive size: ~5Tb
- Ingest rate: ~2Gb/day
- Distribution rate: ~40Gb/day, 400K files/day
- Files:
  - Data (L1, L1B), products (L2) derived from these data, and information about data and products
  - Multi-day, daily, hourly, sub-hourly
  - Varying latencies (minutes, hours, days)
- Metadata:
  - Non-standard, data type specific
  - Extracted from data (not all products) and loaded into database (Oracle now, MySQL RSN)
  - Internal access to database

# CDDIS User Community

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- Expert Users
- Production Users
- Novice/Occasional Users

# Expert Users

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- Majority may be considered “Science Team” type users
  - Analysis Centers supporting IAG services, tasked with providing standard products as per service specifications
  - U.S. and international groups who produce products for use in higher level products (e.g., orbits for GRACE, Jason, etc.; ionosphere/troposphere products for weather models)
- Require continuous access to data for generation of products on pre-determined schedules
- Use scripts to automate retrieval of required files through ftp
- ~40-50% of CDDIS user base

# Production Users

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- Retrieve files from CDDIS to equalize data holdings among other data centers supporting IAG services
- Use scripts to automate retrieval of required files through ftp
- ~20% of CDDIS user base

# Novice/Occasional Users

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- Need to explore the contents of the archive by spatial, temporal, platform, or parameter specifications
- Access archive through ftp to:
  - Pick and chose data or products
  - Grab large subsets of data on irregular basis
- Examples:
  - Federal, state, international surveyors who use GNSS reference station data for local measurements
  - Military users who download SLR data for calibration of radars for space debris tracking
  - Managers who need statistics on network data production (metadata search)
  - ...
- 30% of CDDIS user base

# CDDIS Usage Statistics

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- ~9.5 M files, 1.1 Tb/month:
  - Science Users: 4 M files, 440 Gb/month
  - Production Users: 2.5 M files, 310 Gb/month
  - General Users: 3 M files, 300 Gb/month

# Data Discovery: Input and Output

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- Specify (any/all):
  - Temporal: Year, date/time, range
  - Spatial: Region, lat/lon, range
  - Target: Satellite (SLR, DORIS)
  - Designation: Station name/number/code
  - Parameter: Receiver type (GNSS), event timer (SLR), antenna type (GNSS, VLBI), ...
- Results:
  - List of sites satisfying specifications
  - List of data holdings satisfying specifications
  - Metadata relevant to selection
  - ...



# Example: UNAVCO

<http://facility.unavco.org/data/dai2/app/dai2.html>

**UNAVCO** Data Archive Interface (alpha) Search History Download Cart

Search   Stations  Campaign sites  All Current results: **12** items

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### Metadata

4-char Code:

Site/Marker Name:

Network/Campaign:

4-char Code	Site/Marker Name	Latitude	Longitude	Earliest Date
ABPO	Ambohimpanompo, M	-19.018	47.229	2007 Nov 1
HRAO	Hartebeesthoek RAO	-25.8901	27.687	1996 Sep 2
MAD2	Madrid Deep Space Tr	40.4292	-4.2497	1997 Jul 07
MADR	Madrid Deep Space Tr	40.4292	-4.2497	1992 Jul 14
<b>MBAR</b>	<b>Mbarara</b>	<b>-0.6015</b>	<b>30.7379</b>	<b>2001 Jul 17</b>
RABT	Rabat, EMI	33.9981	-6.8543	2000 May 1

Metadata Options

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### Spatial

Map Satellite Hybrid Terrain

Bounding box | Radius

N  
50.4827  
W -20.9979 64.78  
-51.8656  
S

Station Campaign site

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### Temporal

Temporal Options

Start: 2009 Jan 01  
to  
End: 2009 Jan 08

User feedback

### Download Cart

[Master file list](#)

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**Summary**

73 station files	23.6 Mb
Totals: 73 files	23.6 Mb

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[File list](#)

1 station with 6 f...	1.8 Mb
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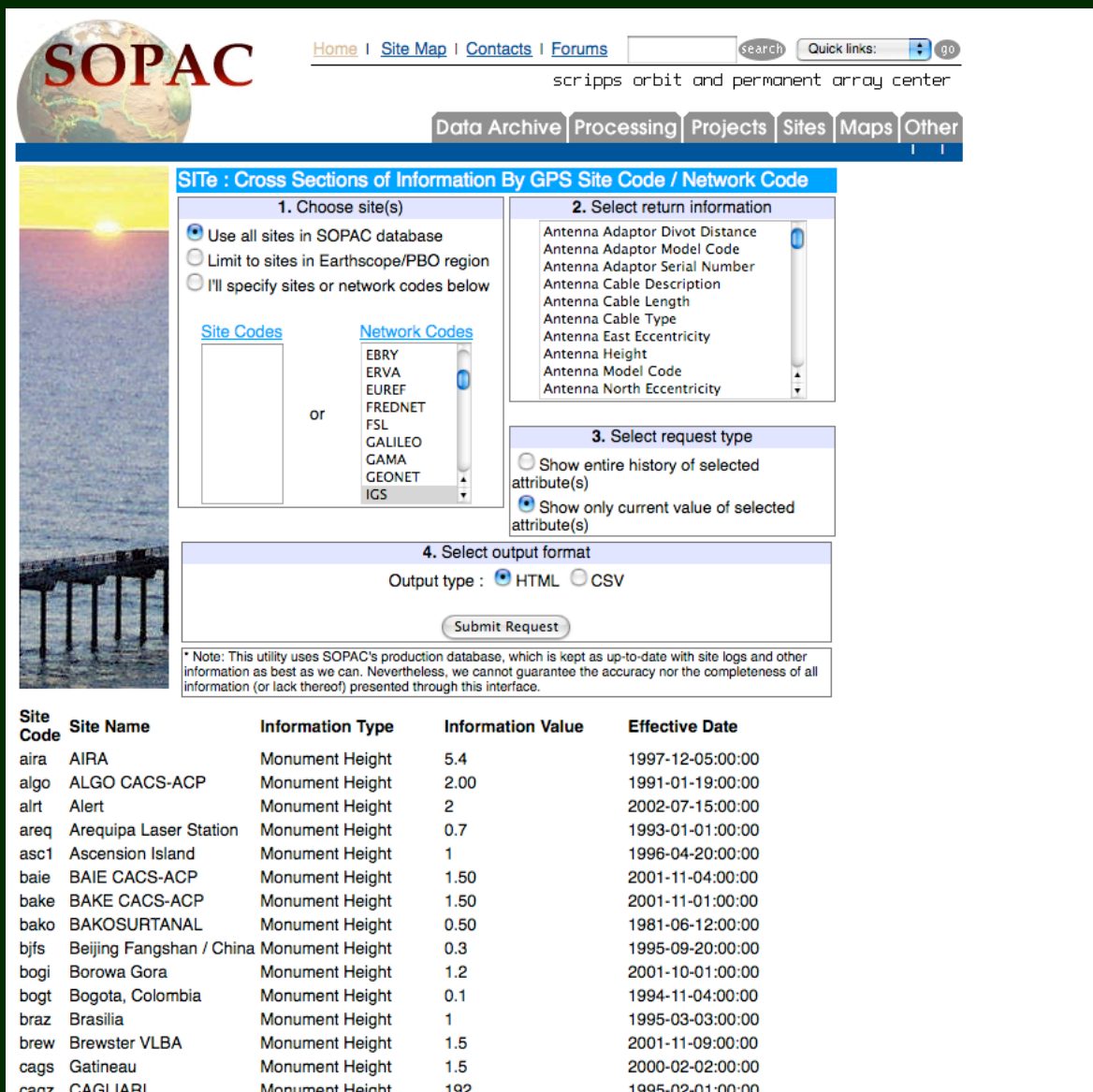
[File list](#)

12 stations with ...	21.8 Mb
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# Example: SIO/SOPAC

<http://sopac.ucsd.edu/cgi-bin/SITe.cgi>



**SOPAC** Home | Site Map | Contacts | Forums  search Quick links:  scripps orbit and permanent array center

Data Archive | Processing | Projects | Sites | Maps | Other

### SITE : Cross Sections of Information By GPS Site Code / Network Code

**1. Choose site(s)**

Use all sites in SOPAC database  
 Limit to sites in Earthscope/PBO region  
 I'll specify sites or network codes below

Site Codes or Network Codes

EBRY  
ERVA  
EUREF  
FREDNET  
FSL  
GALILEO  
GAMA  
GEONET  
IGS

**2. Select return information**

Antenna Adaptor Divot Distance  
Antenna Adaptor Model Code  
Antenna Adaptor Serial Number  
Antenna Cable Description  
Antenna Cable Length  
Antenna Cable Type  
Antenna East Eccentricity  
Antenna Height  
Antenna Model Code  
Antenna North Eccentricity

**3. Select request type**

Show entire history of selected attribute(s)  
 Show only current value of selected attribute(s)

**4. Select output format**

Output type :  HTML  CSV

\* Note: This utility uses SOPAC's production database, which is kept as up-to-date with site logs and other information as best as we can. Nevertheless, we cannot guarantee the accuracy nor the completeness of all information (or lack thereof) presented through this interface.

Site Code	Site Name	Information Type	Information Value	Effective Date
aira	AIRA	Monument Height	5.4	1997-12-05:00:00
algo	ALGO CACS-ACP	Monument Height	2.00	1991-01-19:00:00
alrt	Alert	Monument Height	2	2002-07-15:00:00
areq	Arequipa Laser Station	Monument Height	0.7	1993-01-01:00:00
asc1	Ascension Island	Monument Height	1	1996-04-20:00:00
baie	BAIE CACS-ACP	Monument Height	1.50	2001-11-04:00:00
bake	BAKE CACS-ACP	Monument Height	1.50	2001-11-01:00:00
bako	BAKOSURTANAL	Monument Height	0.50	1981-06-12:00:00
bjfs	Beijing Fangshan / China	Monument Height	0.3	1995-09-20:00:00
bogi	Borowa Gora	Monument Height	1.2	2001-10-01:00:00
bogt	Bogota, Colombia	Monument Height	0.1	1994-11-04:00:00
braz	Brasilia	Monument Height	1	1995-03-03:00:00
brew	Brewster VLBA	Monument Height	1.5	2001-11-09:00:00
cags	Gatineau	Monument Height	1.5	2000-02-02:00:00
caz7	CAGI IARI	Monument Height	192	1995-02-01:00:00

# Example: SIO/JPL GPS Explorer

<http://geoapp03.ucsd.edu/gridsphere/gridsphere>

The screenshot displays the GPS Explorer web application interface. At the top, it says "GPS Explorer BETA" and "Firefox 3 (required)". The main navigation bar includes "Overview Port" and "SOMI for Portals Portlet".

The "SOMI for Portals Portlet" shows a map of California with a query for "CGPS Stations" resulting in 362 features. The selected feature is "gold0000" with coordinates (35.421, -116.89). The "My Site Groups Portlet" shows a list of site groups and functions, with "My saved/active group(s)" set to "GGOS-demo".

The "Single Site Information Portlet" provides detailed information for site "gold":
 

- Site code: gold
- Data begin date: 2008-12-04
- Data end date: 2009-01-08
- Processed data source: SOPAC GLOBK

The "Time Series Plots" section shows a plot of "gold north slope(m) (mm/yr)" from 1992 to 2008. The plot shows a clear seasonal cycle with a peak in 2008. The plot is titled "gold north slope(m) (mm/yr): -4.8 +/- 0.1 (1992.49;1999.79; -3.2 +/- 0.1 (1999.79;2009.01); rms: 1.7 mm".

The "Current Metadata" section includes:
 

- Site Name: Goldstone Deep Space Tracking Station
- Four Character ID: GOL2
- IERS Domes Number: H0405S031
- Monument Description: STEEL MAST
- Date Installed: 1989-12-15T00:00Z
- City or Town: Goldstone
- State or Province: California

The "NEU Velocities" section shows the following data:
 

Date	North (m/yr)	East (m/yr)	Up (m/yr)	North Sigma	East Sigma	Up Sigma
gold 1992-06-28T00:00:00	-4.7490	-18.0100	-1.7880	0.1600	0.3050	1.0130
gold 1999-10-16T00:00:00	-3.2570	-18.3440	0.6100	0.1460	0.2800	0.7730

The "XYZ Coordinates" section shows the following data:
 

Date	X (m)	Y (m)	Z (m)	X Sigma	Y Sigma	Z Sigma
gold 2008-12-04T12:00:00	-2353614.3846	-4641385.3049	3676976.4141	0.0027	0.0047	0.0037
gold 2008-12-05T12:00:00	-2353614.3822	-4641385.3035	3676976.4116	0.0027	0.0050	0.0037
gold 2008-12-06T12:00:00	-2353614.3832	-4641385.3039	3676976.4129	0.0029	0.0049	0.0037
gold 2008-12-07T12:00:00	-2353614.3836	-4641385.3040	3676976.4110	0.0030	0.0052	0.0040

The "RINEX file links" section lists several RINEX files, including "2008/339/gold3390.08d.Z" and "2008/343/gold3430.08d.Z".

# Background Slides



# Scientific Contributions of the IGS, ILRS, IVS, and IDS

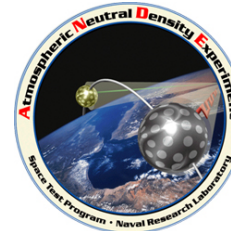
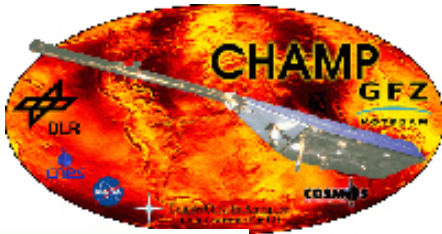
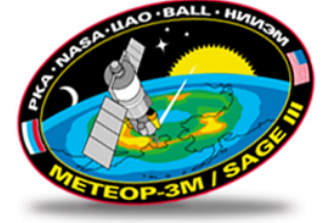
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- Terrestrial Reference Frame (TRF):
  - Station positions and velocities: GNSS, SLR, VLBI, DORIS
  - TRF scale and temporal variations: VLBI, SLR
  - Network densification: GNSS
  - Homogenous network distribution: DORIS
- Celestial Reference Frame: VLBI
- Precise Orbit Determination (POD):
  - Accurate satellite ephemerides: GNSS, SLR, DORIS
  - Calibration/validation for remote sensing missions, instruments: SLR, GNSS
  - Sea level monitoring: GNSS, SLR, DORIS
- Earth Orientation Parameters (EOP):
  - Polar motion and rates: VLBI, SLR, GNSS, DORIS
  - Length-of-day: GNSS, SLR, DORIS
  - UT1-UTC and long-term stability of nutation: VLBI
- Atmosphere:
  - Tropospheric zenith delays: GNSS, VLBI
  - Global maps of ionosphere mean electron content: GNSS, DORIS
  - Limb sounding for global profiles of water vapor: GNSS
- Gravity:
  - Static and time-varying coefficients of the Earth's gravity field: DORIS, SLR
  - Total Earth mass: SLR
  - Temporal variations of network origin with respect to Earth center of mass: SLR
- Timing:
  - Station and satellite clock solutions: GNSS
  - Time and frequency transfer between time laboratories: GNSS
- Fundamental Physics:
  - General relativity and alternative theories: SLR/LLR
  - Light bending, time dilation: VLBI

# Space Geodesy Data Records

Data Record	Data Set	Processing Level	Granule	Time Span
SLR/LLR	Round trip time of flight (full-rate)	1A	Daily, sub-daily	1975-date
	Round trip time of flight (normal point)	1A	Daily, sub-daily	1991-date
	Station positions	2	Weekly	1992-date
	EOP (polar motion, length of day)	2	Weekly	1992-date
GNSS	Pseudorange and phase observations (RINEX)	1A	Daily, sub-daily	1992-date
	Station positions	2	Weekly	1992-date
	Clocks	2	Weekly, daily, sub-daily	1992-date
	Orbits	2	Weekly, daily, sub-daily	1992-date
	EOP (polar motion and rates, length of day)	2	Weekly, daily, sub-daily	1992-date
	Zenith tropospheric path delay estimates	2	Weekly, daily	1997-date
	Global ionosphere maps	2	Weekly, daily	1998-date
VLBI	Correlated measurement experiment data bases	1A	Daily	1979-date
	Baselines	2	Daily	1979-date
	EOP	2	Daily	1979-date
	Station positions	2	Daily	1979-date
	Source positions	2	Daily	1979-date
	Zenith tropospheric path delay estimates	2	Weekly	2002-date
DORIS	Time-tagged station to satellite range	1A	10-day cycle	1990-date
	Station positions	2	Daily	1993-date
	Derived vertical total electron content (VTEC)	2	Daily	2002-date
	EOP (polar motion, length of day)	2	Daily	2002-date

# Supported Missions and Programs





# CDDIS Resources

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- CDDIS activity in Code 690 (690.1) and co-located with science and technology staff (694 and 698) in Building 33
- Staffing
  - Civil Servants (0.65 FTE)
  - Contractors (2.0 FTE)
  - System administration (0.25 FTE)
- Computer resources
  - Operational server
    - Dell server running Linux
    - Oracle
    - Backup server (currently non-operational)
    - 5+ Tbytes RAID
  - Recently-acquired distributed system
    - Apple Xserves running Mac OS; Dell servers running Linux
    - MySQL
    - Processing, incoming, and outgoing activities on different servers with backup for automated failover
    - 18 Tbytes xSAN
  - Both systems in Building 33

# CDDIS Metadata in the GCMD

Record Search Query: DataCenter>GOVERNMENT AGENCIES-U.S. FEDERAL AGENCIES>NASA>NASA/GSFC/S&EDC/CDDIS

## Satellite Laser Ranging Data from NASA CDDIS

Entry ID: CDDIS\_SLR\_data

[\[ View Brief Record \]](#) [\[ Get Data \]](#) [\[ Update this Record \]](#)

### Summary

In Satellite Laser Ranging (SLR), a short pulse of coherent light generated by a laser (Light Amplification by Stimulated Emission of Radiation) is transmitted in a narrow beam to illuminate corner cube retroreflectors on the satellite. The return signal, typically a few photons, is collected by a telescope and the time-of-flight is measured. Using information about the satellite's ...

[Click to View Full Summary](#)

### Geographic Coverage



### Spatial coordinates

N: 90.0 S: -90.0 E: 180.0 W: -180.0

### Data Set Citation

Dataset Creator: M. Pearlman, J. Degnan, J. Bosworth  
Dataset Title: The International Laser Ranging Service  
Dataset Series Name: Proceedings of session "New Trends in Space Geodesy" 33rd COSPAR Scientific Assembly  
Dataset Release Date: July 2002  
Dataset Release Place: The Netherlands  
Dataset Publisher: Elsevier Ltd.  
Version: Vol. 30, No. 2, pp. 135-143  
Issue Identification: Advances in Space Research  
Data Presentation Form: 33rd COSPAR Scientific Assembly, Warsaw, July 2000  
Online Resource: [http://www.sciencedirect.com/science?\\_ob=ArticleURL&\\_udi=B6V3S-461Z...](http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V3S-461Z...)

### Temporal Coverage

Start Date: 1976-01-01

### Location Keywords

[GEOGRAPHIC REGION > GLOBAL](#)

### Data Resolution

Temporal Resolution: 1 Day  
Temporal Resolution Range: Daily - < Weekly

### Data Center

Crustal Dynamics Data Information System, Solar System Exploration Division, Goddard Space Flight Center, NASA [\[ description \]](#)

Data Center URL: <http://cddis.gsfc.nasa.gov/>

### Data Center Personnel

Name: [CAREY NOLL](#)  
Phone: 301-614-6542  
Fax: 301-614-6015  
Email: Carey.E.Noll at nasa.gov  
Contact Address:  
NASA Goddard Space Flight Center  
Code 690  
City: Greenbelt  
Province or State: MD  
Postal Code: 20771  
Country: USA

### Distribution

Distribution Media: On-line  
Distribution Size: 1-10 Mb/day  
Distribution Format: On-line  
Fees: None

### Personnel

[CAREY NOLL](#)  
Role: TECHNICAL CONTACT  
Phone: 301-614-6542  
Fax: 301-614-6015  
Email: Carey.E.Noll at nasa.gov  
Contact Address:  
NASA Goddard Space Flight Center  
Code 690  
City: Greenbelt  
Province or State: MD  
Postal Code: 20771  
Country: USA

### Related URL

Link: [GET DATA](#)  
Description: SLR data holdings at CDDIS via ftp  
[Click to view more](#)

### Publications/References

Pearlman, M.R., Degnan, J.J., and Bosworth, J.M., "The International Laser Ranging Service", Advances in Space Research, Vol. 30, No. 2, pp. 135-143, July 2002, DOI:10.1016/S0273-1177(02)00277-6.

### Creation and Review Dates

DIF Creation Date: 2000-11-13  
Last DIF Revision Date: 2008-12-04

- [Reformat as FGDC document](#)
- [View Text Only Format](#)

## Index of ftp://cddis.gsfc.nasa.gov/pub/slr/data/

[Up to higher level directory](#)

Name	Size	Last Modified
<a href="#">fr</a>		12/19/2008 10:11:00 AM
<a href="#">fr_ord</a>		12/19/2008 10:16:00 AM
<a href="#">itdf</a>	7/20/2007	12:00:00 AM
<a href="#">npt</a>		12/19/2008 10:10:00 AM
<a href="#">npt_ord</a>		12/19/2008 10:15:00 AM
<a href="#">reports</a>		10/6/2006 12:00:00 AM
<a href="#">slr_data_corrections.snv</a>	75 KB	7/15/2003 12:00:00 AM
<a href="#">test_ord</a>		1/28/2009 9:11:00 AM

# CDDIS Supplemental Descriptions in the GCMD

## Crustal Dynamics Data Information System, Solar System Exploration Division, Goddard Space Flight Center, NASA

### Data Center Description

The Crustal Dynamics Data Information System (CDDIS) is a dedicated data center supporting the international space geodesy community, providing easy and ready access to a variety of data sets, products, and information about these data. The data center was established in 1982 as a dedicated data bank to archive and distribute all Crustal Dynamics Project-acquired data and information about these data. Today, the CDDIS continues to serve as the NASA archive and distribution center for space geodesy data, particularly Global Navigation Satellite System (GNSS, currently GPS and GLONASS), laser ranging, Very Long Baseline Interferometry (VLBI), and Doppler Orbitography and Radiopositioning Integrated by Satellite (DORIS) data. The specialized nature of the CDDIS lends itself well to enhancement to accommodate diverse data sets and user requirements. All data sets and metadata extracted from these data sets are accessible to scientists through ftp and the Web; general information about each data set is accessible via the Web.

The data archive supports NASA's space geodesy activities within the Science Mission Directorate. The CDDIS data system and its archive have become increasingly important to many national and international programs, particularly several of the operational services within the International Association of Geodesy (IAG). The CDDIS serves as one of the primary data centers for the following IAG services: the International GNSS Service (IGS), the International Laser Ranging Service (ILRS), the International VLBI Service for Geodesy and Astrometry (IVS), the International DORIS Service (IDS), and the International Earth Rotation and Reference Systems Service (IERS).

CDDIS Contact:  
Carey E. Noll  
NASA Goddard Space Flight Center  
Code 690  
Greenbelt, MD 20771, USA  
Email: Carey.E.Noll@nasa.gov

CDDIS Home Page: <http://cddis.gsfc.nasa.gov/>

### Data Center URL

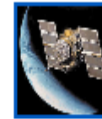
URL: <http://cddis.gsfc.nasa.gov/>

## International GNSS Service

### Project Description

The International GNSS Service (IGS), formerly the International GPS Service, is a voluntary federation of more than 200 worldwide agencies that pool resources and permanent GPS and GLONASS station data to generate precise GNSS products. The IGS is committed to providing the highest quality data and products as the standard for Global Navigation Satellite Systems (GNSS) in support of Earth science research, multidisciplinary applications, and education. Currently the IGS includes two GNSS, GPS and the Russian GLONASS, and intends to incorporate future GNSS. The IGS collects, archives, and distributes GNSS observation data sets of sufficient accuracy to satisfy the objectives of a wide range of applications and experimentation. These data sets are used by the IGS to generate the data products (high accuracy GNSS satellite ephemerides, Earth rotation parameters, coordinates and velocities of the IGS tracking stations, GNSS satellite and tracking station clock information, timescale products, ionospheric and tropospheric information). In particular, the accuracies of IGS products are sufficient for the improvement and extension of the International Terrestrial Reference Frame (ITRF), the monitoring of solid Earth deformations, the monitoring of Earth rotation and variations in the liquid Earth (sea level, ice-sheets, etc.), for scientific satellite orbit determinations, ionosphere monitoring, and recovery of precipitable water vapor measurements. These activities endeavor to advance scientific understanding of the Earth system components and their interactions, as well as to facilitate other applications benefiting society. The Service also develops the necessary standards and specifications and encourages international adherence to its conventions.

Information provided by <http://igs.org>



**Platform:** GPS > Global Positioning System Satellites

[▶ Click to view more](#)

**Synonymous Platform Names:**

[▶ Click to view more](#)

**Platform-based Instruments:**

[▶ Click to view more](#)

**Orbit**

**Orbit Altitude:** 20,200 km

**Orbit Type:** MEO > Semi-Synchronous > Navigation

**Related Data Sets**

[View all records related to this platform in GCMD](#)

**Description**

The Global Positioning System (GPS) Satellite is a system of satellites developed by the US Department of Defense to provide all-weather round-the-clock navigation capabilities for military ground, sea, and air forces. Since its implementation, GPS has also become an integral asset in numerous civilian applications and industries around the globe, including recreational uses (e.g. boating, aircraft, hiking), corporate vehicle fleet tracking, and surveying.

[▶ Click to view more](#)

**Online Resource:**

<http://msl.jpl.nasa.gov/Programs/gps.html>

**Primary Sponsors:**

U.S. Department of Defense