



**CDDIS**

NASA's Archive of Space Geodesy Data

# The CDDIS: Supporting Scientific Analysis for 25+ Years Using Space Geodesy Data and Products

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- Archive contents
- User profile

# CDDIS Overview

- Crustal Dynamics Data Information System, NASA's active archive of space geodesy data, products, and information
- Established in 1982 as a dedicated data bank to archive and distribute all Crustal Dynamics Project-acquired data and information about these data
- Continues to serve as an archive and distribution center for space geodesy data, particularly GNSS, laser ranging, VLBI, and DORIS data
- Has extensive partnerships through the International Association of Geodesy (IAG) serving as one of the primary data centers for the IAG services and its observing system GGOS (Global Geodetic Observing System)
- Past CDDIS funding through NASA's Solid Earth Research Program; now funded through NASA Earth Science Data Systems Core Program

# Space Geodesy (1/3)

- Geodesy provides a foundation for all Earth observations
- Space geodesy is the use of precise measurements between space objects (e.g., orbiting satellites, quasars) to determine
  - Positions of points on the Earth
  - Position of the Earth's pole
  - Earth's gravity field and geoid



**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 pseudo-range, 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



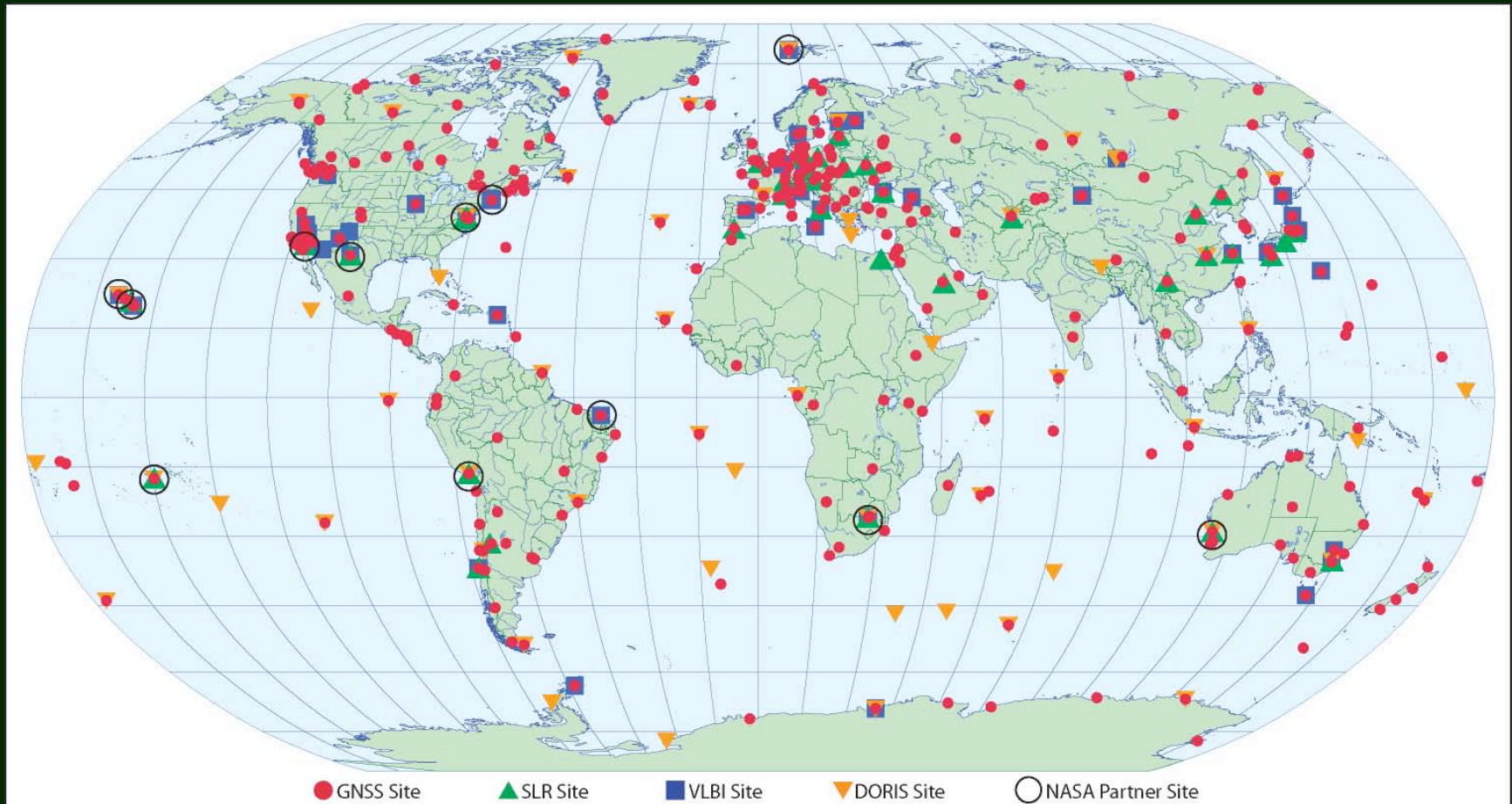
# Space Geodesy (2/3)

- Data from the CDDIS archive are utilized for direct science observations and geodetic studies, e.g., plate motion, gravity field, earthquake displacements, Earth orientation, atmospheric angular momentum, etc.
- Data also contribute to the determination of the Terrestrial Reference Frame, an accurate set of positions and velocities
  - TRF provides the essential stable coordinate system that allows measurements to be linked over space and time; independent of the technology used to define it
  - Space geodetic networks (GNSS, SLR, VLBI, DORIS) provide the critical infrastructure necessary to develop and maintain the TRF
- Data used for Precise Orbit Determination (POD)
  - CDDIS archive of SLR and DORIS data accessed to calculate and verify precise orbits for Earth observation missions (e.g., ERS-1/2, ALOS, Jason-1/2, Envisat, TOPEX, etc.)
  - CDDIS archive of SLR data and GPS flight receiver data also utilized for POD efforts for other geophysical missions (e.g., GFO-1, CHAMP, GRACE, ICESat, GOCE, etc.)
- Additional products include atmosphere measurements to aid in weather forecasting, etc.
- CDDIS providing support to the LRO-LR experiment through its laser ranging archive; also provides development support and hosting of LRO-LR real-time Web site for LOLA SOC

# Space Geodesy (3/3)

- Data
  - GNSS: 421 sites tracking GPS, GLONASS
  - Laser Ranging (SLR and LLR): 42 sites tracking 35+ satellites (including the Moon)
  - VLBI: 39 sites
  - DORIS: 57 sites tracking 6 satellites
  - Stations in the GNSS, SLR/LLR, VLBI, and DORIS networks generate point data on a multi-day, daily, hourly, and/or sub-hourly basis
- 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)
  - ...
  - Products provided weekly, daily basis

# CDDIS Data: Global Networks



# Scientific Contributions of Space Geodesy

- 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 In the CDDIS

∴	Data Record	Data Set	Processing Level	Granule	Time Span
		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
	SLR/LLR	Station positions	2	Weekly	1992-date
		EOP (polar motion, length of day)	2	Weekly	1992-date
		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
	GNSS	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
		Correlated measurement experiment data bases	1A	Daily	1979-date
		Baselines	2	Daily	1979-date
	VLBI	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
		Time-tagged station to satellite range	1A	10-day cycle, daily	1990-date
	DORIS	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



# IAG Services

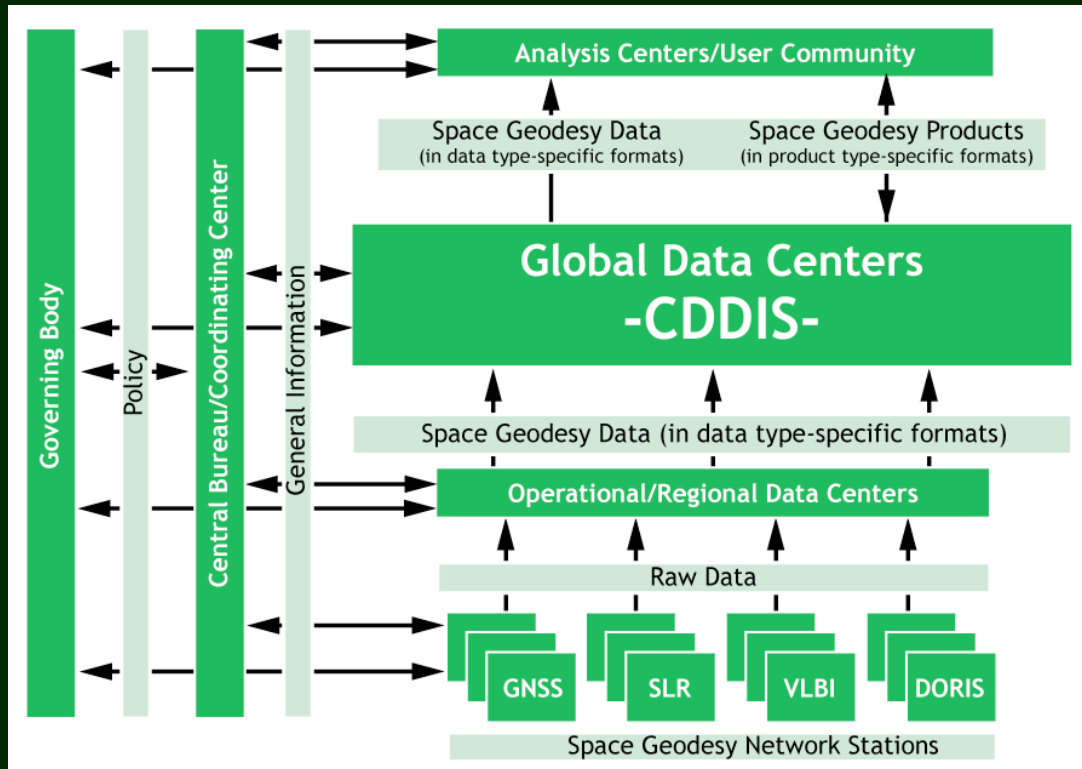
- Services function as cooperating federations dedicated to a particular type of data
- Provide data and products on an operational basis to geodesy analysts as well as a broader scientific community
- Examples of a successful model of community management:
  - develop standards
  - self-regulating
  - 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

- 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 community for CDDIS archive

# Flow of Files to/from CDDIS

(Information, Data, Products)



- **Network Stations**
  - Continuously operational
  - Timely flow of data
- **Data Centers**
  - Interface to network stations
  - Perform QC and data conversion activities
  - Archive data for access to analysis centers and users
- **Analysis Centers and Coordinators**
  - Provide products to users (e.g., station coordinates, precise satellite orbits, Earth orientation parameters, atmospheric products, etc.)
- **Central Bureau**
  - Management of service
  - Facilitate communications
  - Coordinate activities
- **Governing Body**
  - General oversight of service
  - Future direction

# CDDIS Archive

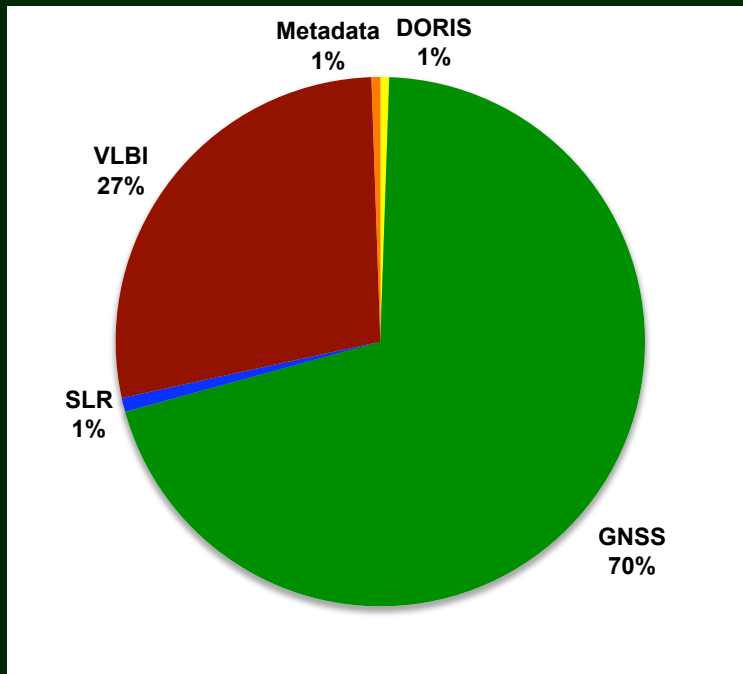
- Archive size: ~5Tb
- Ingest rate: ~90Gb/1 M files per month
- Distribution rate: ~1.4 Tb/12.7 M files per month
- File size is typically <2Mb/data “granule”, <10Mb/derived product “granule”
- Easy to add new data types/data sets
- Files:
  - Data, products derived from these data, and information about 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 relational database
  - Internal access to database

# CDDIS User Community

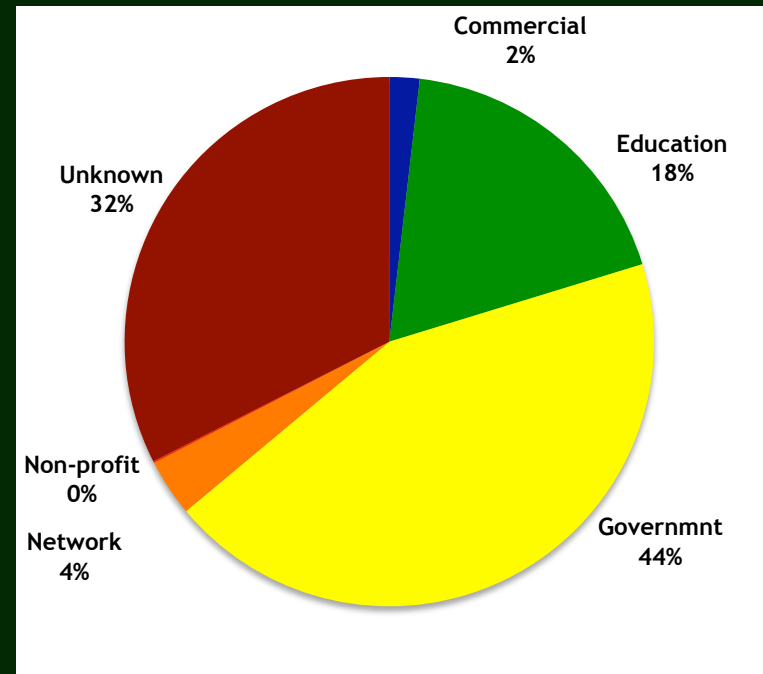
- Expert Users (e.g., Science Teams)
  - Science Teams:
    - Analysis Centers supporting IAG services, tasked with providing standard products as per service specifications
    - U.S. and international groups who produce products for use in higher level products (e.g., orbits for GRACE, Jason, etc.; ionosphere/troposphere products for weather models)
    - Require continuous access to data for generation of products on pre-determined schedules
  - Production Users:
    - 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
- Novice/Occasional Users
  - 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

# CDDIS Archive Statistics

Archive contents by data type:



User distribution profile:

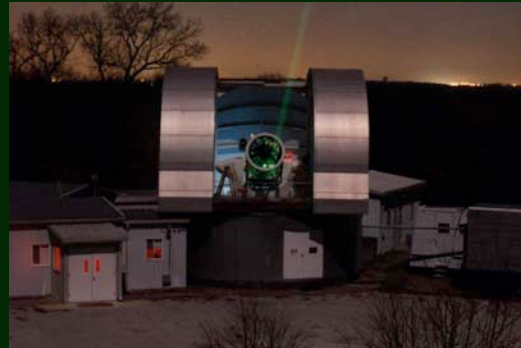


# Future Developments: Enhancing CDDIS Data Discovery

- Plan 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)
- 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
  - ...

# Goddard Geophysical and Astronomical Observatory (GGAO)

- GGAO is home to NASA's Satellite Laser Ranging (SLR) since its development in the early 1960s
- GGAO is one of only two currently active sites in the world to have all four geodetic techniques (SLR, VLBI, GNSS, DORIS) co-located
- GGAO is located 3 miles from Goddard; Code 694 responsible for the facility





# Supported Missions and Programs

