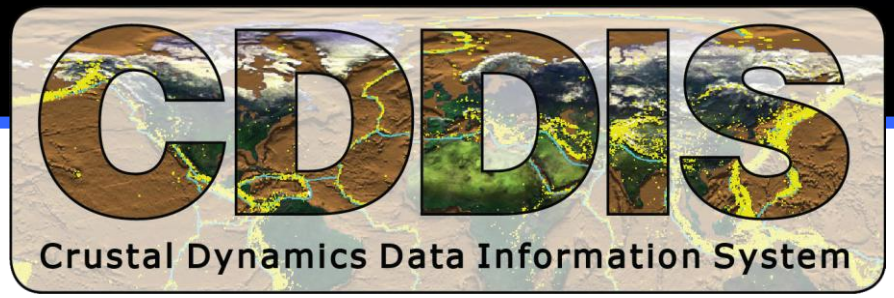


The Crustal Dynamics Data Information System: NASA's Archive of Space Geodesy Data

Carey Noll, CDDIS Manager
Lori Tyahla, User Services, Webmaster

May 28, 2014

Overview

- Introduction, history, and background
- (Space) Geodesy 101
- Archive contents
- User community
- Website and application demo
- Future plans

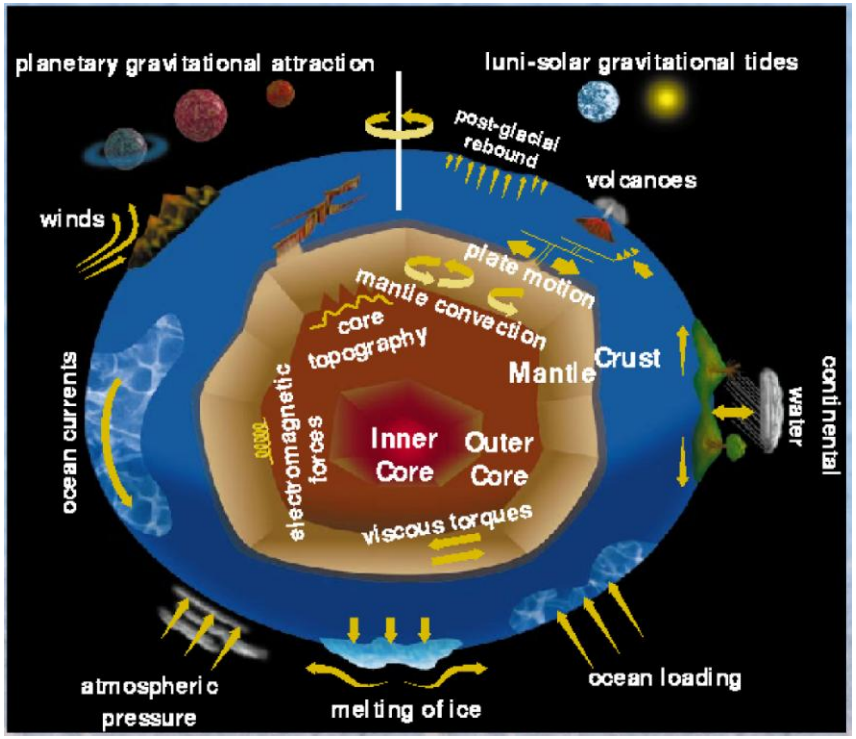
Background

- CDDIS: NASA's active archive of space geodesy data, products, and information
  - GNSS: Global Navigation Satellite System
  - SLR and LLR: Satellite and Lunar Laser Ranging
  - VLBI: Very Long Baseline Interferometry
  - DORIS: Doppler Orbitography and Radio-positioning Integrated by Satellite
- Operations since 1982
- Located at NASA Goddard Space Flight Center
- In October 2007, support for the CDDIS was reorganized at NASA HQ and it became the 12th EOSDIS DAAC
- CDDIS is central to the data management component for NASA's Space Geodesy Project (SGP)
- CDDIS is a regular member of the International Council for Science (ICSU) World Data System (WDS)

Geodesy 101

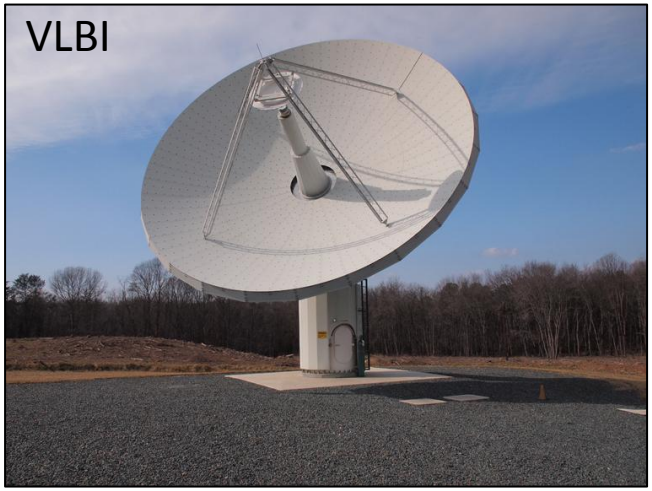
Some think the Earth looks like this:

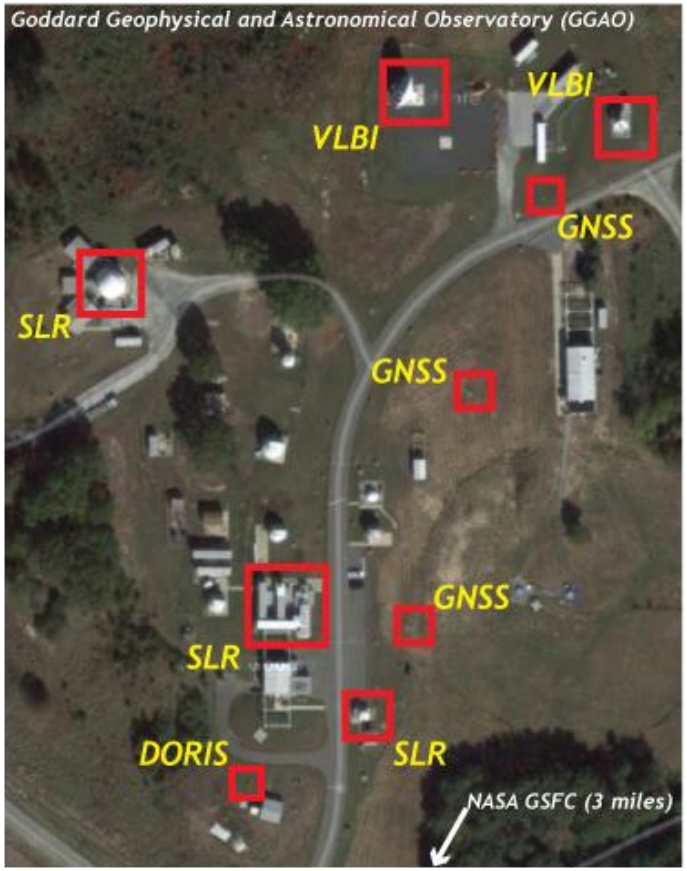
But it actually looks like this:



- Geodesy: Measuring the Earth's geometry, gravity field, and rotation; the size and shape of the Earth
- Space Geodesy: Making these measurements between ground-based instruments and objects in space: GNSS, SLR, VLBI, DORIS

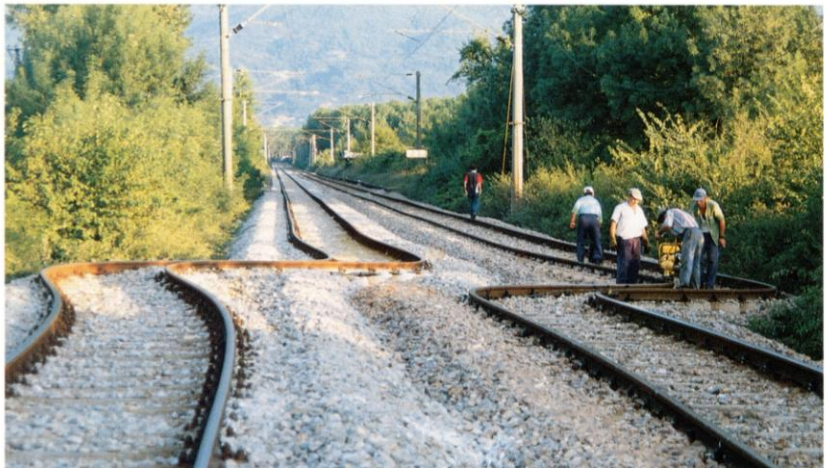
Space Geodesy 101: Instruments





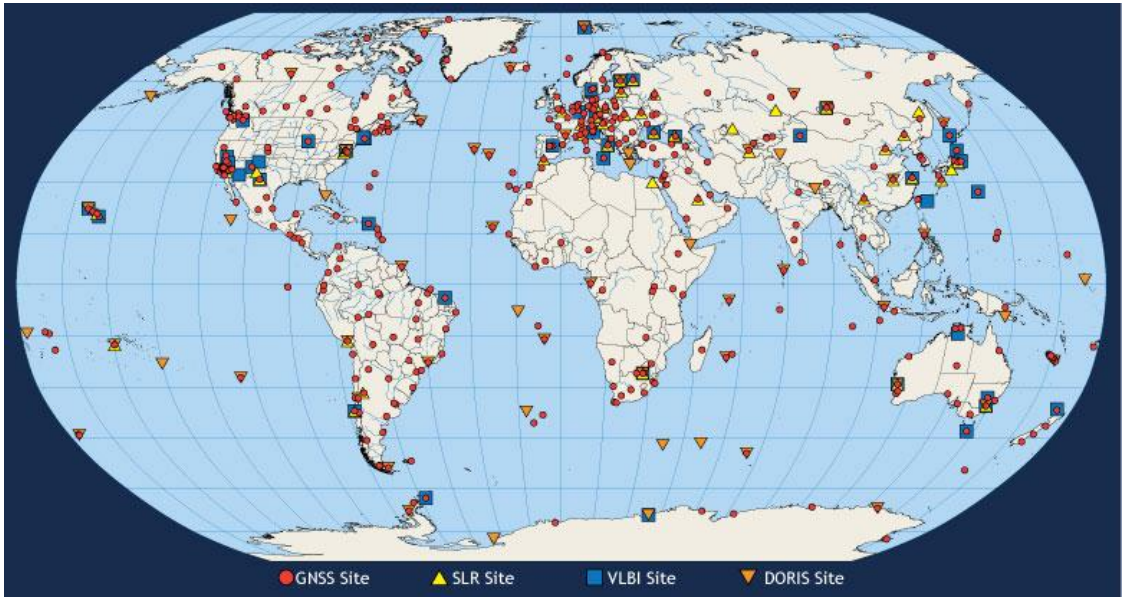
Space Geodesy 101: Motivation

- Everything is moving!
- Earth processes can have a devastating impact on our society and our economies (earthquakes, rising sea level, floods, drought, storms, tsunamis, etc.)
- Geodesy monitors the Earth system, e.g.,
  - Plate motions
  - Solid Earth tides (caused by Sun and Moon)
  - Loading phenomena (ice, ocean, atmosphere)
  - Earthquakes …
- Space geodesy networks are fundamental to the system to monitor and understand Earth processes for both ground and space measurements
- Continuous monitoring is absolutely crucial



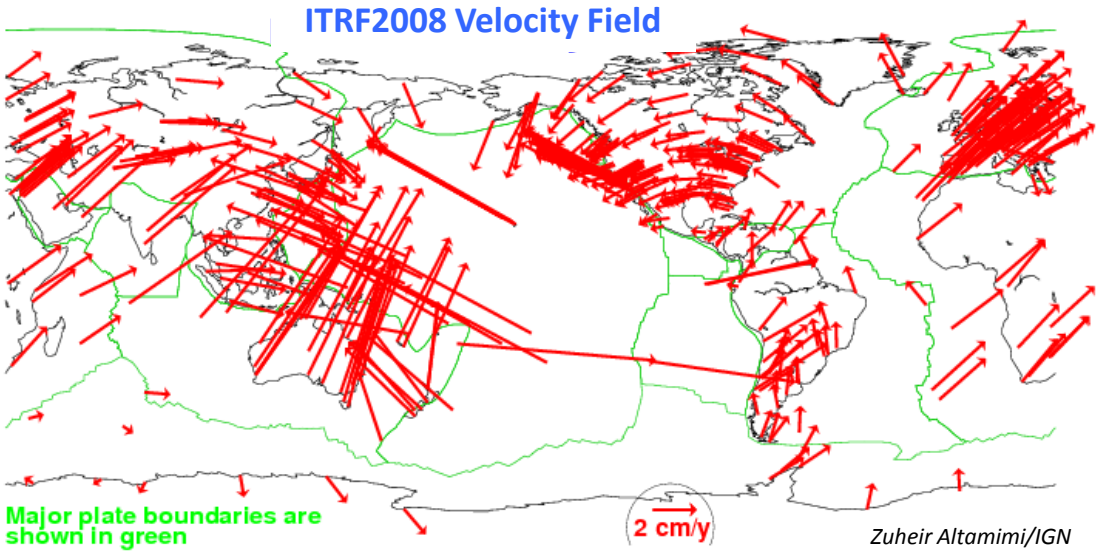
Space Geodesy 101: Global Networks

- Monitoring of Earth processes through the use of global networks of space geodesy stations
- Space geodetic techniques allow scientists to determine the positions and velocities of the stations very precisely, often sub-centimeter level
- Each of the space geodetic techniques has unique properties that bring unique strengths to the determination of this reference frame:
  - Radio vs. optical
  - Terrestrial (satellite) vs. celestial (quasar) reference
  - Broadcast up vs. broadcast down
  - Range vs. range difference measurements
  - Geographic coverage
- Stations provide measurements required to define and maintain a TRF: Terrestrial Reference Frame



Space Geodesy 101: The TRF

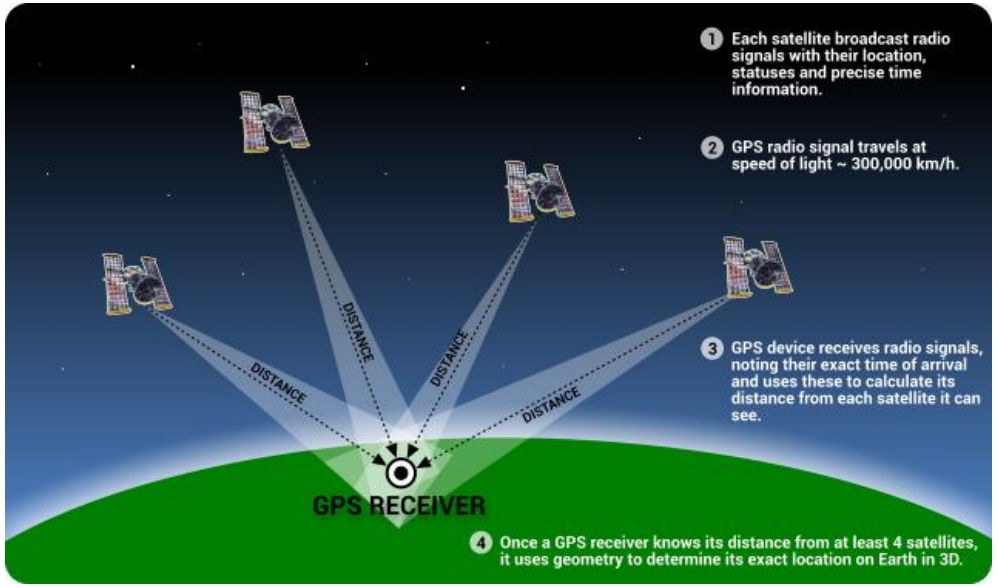
- Space geodetic systems provide the measurements that are needed to define and maintain a Terrestrial Reference Frame (TRF)
- An accurate, stable set of station positions and velocities.
- Provides the stable coordinate system that allows us to measure change (link measurements) over space, time and evolving technologies.
- Foundation for virtually all space-based and ground-based metric observations of the Earth.
- Network measurements must be precise, continuous, robust, reliable, and geographically distributed (worldwide).
- Network measurements interconnected by co-location of different observing techniques



Zuheir Altamimi/IGN
http://itrf.ensg.ign.fr

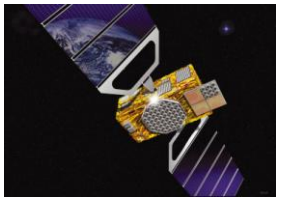
GNSS

- Global Navigation Satellite System
- Space Segment:
  - Satellites equipped with precise clocks transmitting messages to ground (and space-based) receivers
  - GPS (U.S.), GLONASS (Russia), Galileo (Europe), Beidou (China), QZSS (Japan), IRNSS (India)
- Ground Segment:
  - Multi-frequency GNSS receiver and antenna
  - 500+ stations (at CDDIS); 1000's worldwide
- Observable:
  - Station to satellite pseudorange, phase delay
- Characteristics:
  - Comprehensive global network
  - Navigation, surveying, atmospheric and space weather



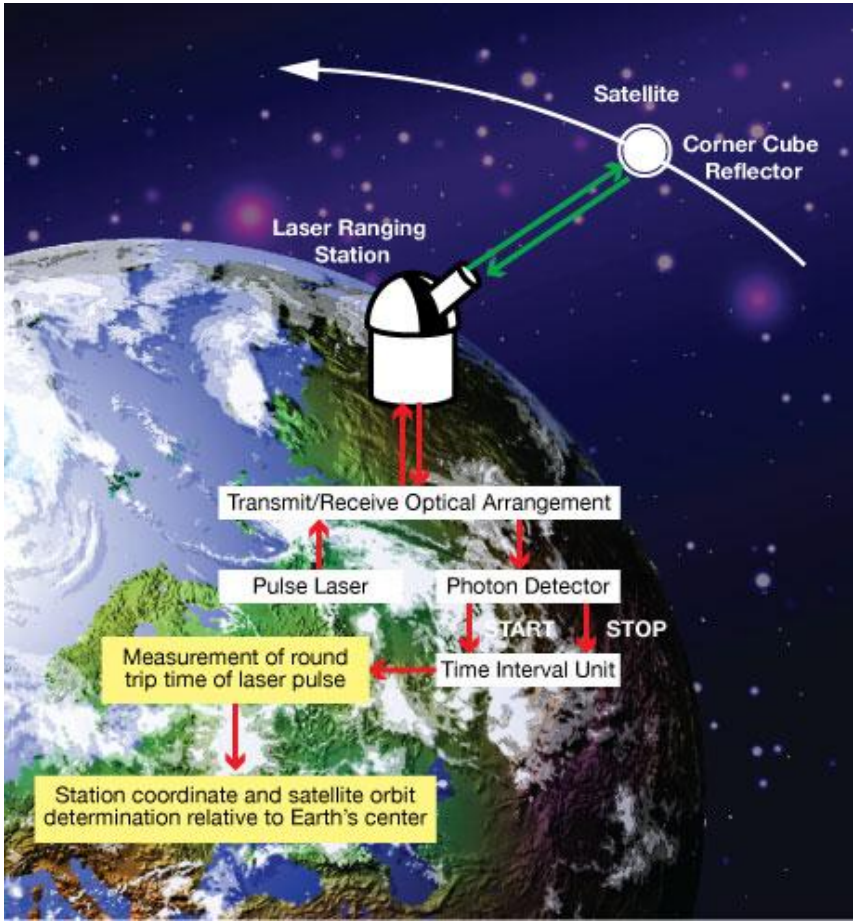
From www.geneko.rs



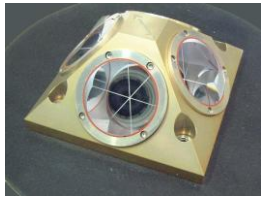



SLR and LLR

- Satellite Laser Ranging and Lunar Laser Ranging
- Space Segment:
  - Satellites equipped with corner cube reflectors
  - 60+ satellites (including the Moon)
- Ground Segment:
  - Short-pulse laser transmitter
  - ~40 sites tracking
- Observable:
  - Two-way range measurement to the satellite
- Characteristics:
  - Passive space segment
  - Simple range measurement
  - Only optical system in the complex

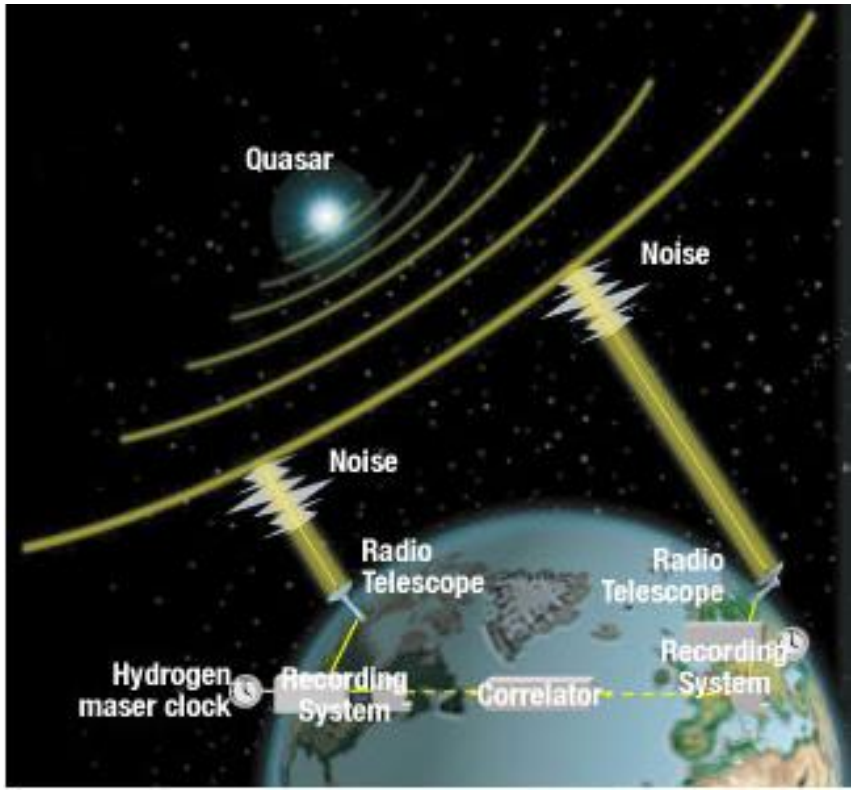


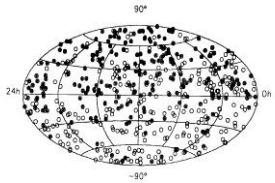





VLBI

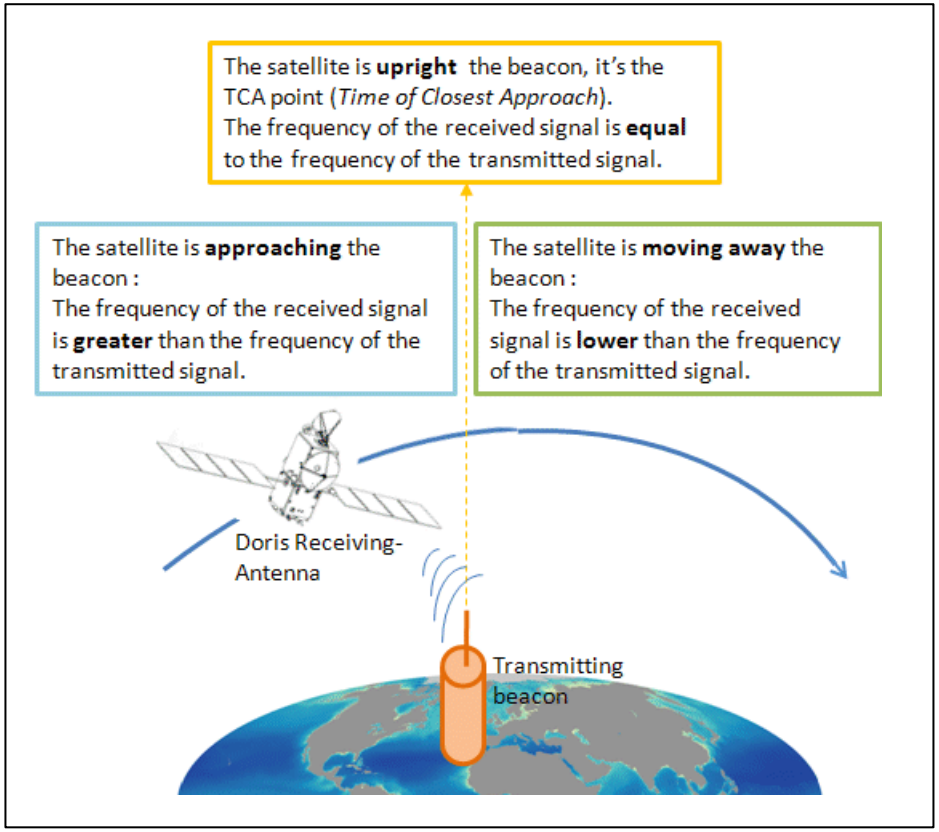
- Very Long Baseline Interferometry
- Space Segment:
  - Quasars (microwave frequencies)
- Ground Segment:
  - Radio telescope equipped with wide band receivers
  - ~45 radio telescopes
- Observable:
  - Time difference between arrival of radio wavefront emitted by a distant quasar at two Earth-based antennas
- Characteristics:
  - Totally passive – radio transmission
  - Large Gbyte data volumes, but moving to wide-band data transmission in near real-time
  - Only method linked to the celestial reference frame (stars)

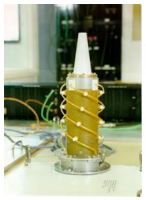


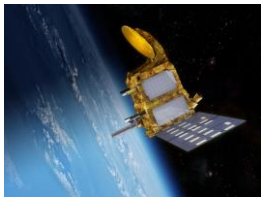


DORIS

- Doppler Orbitography and Radiopositioning Integrated by Satellite
- Space Segment:
  - Satellites equipped with DORIS receiver and uplink hardware
  - 5 satellites
- Ground Segment:
  - Beacons transmitting radiofrequency signals
  - 58 stations
- Observable:
  - Doppler shift on radiofrequency signals
- Characteristics:
  - Global distribution
  - Strong ground system configuration control (single source)

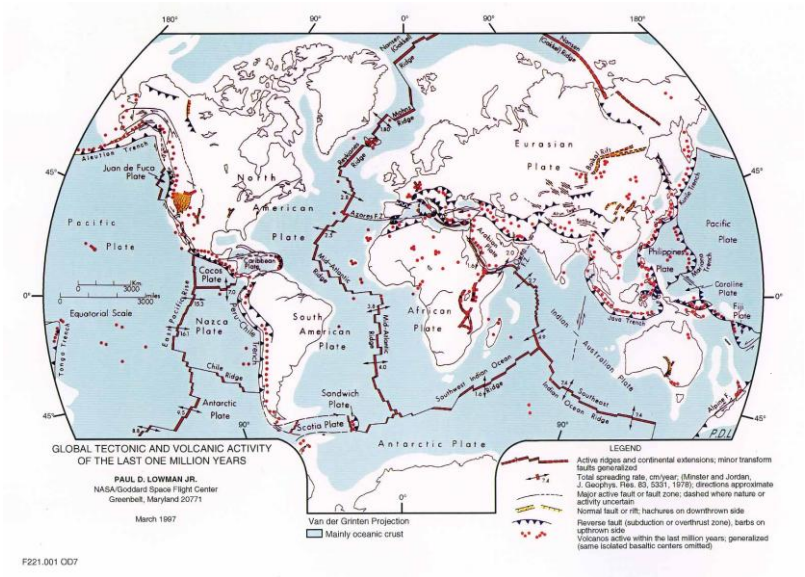


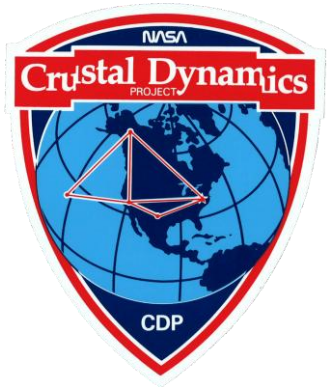


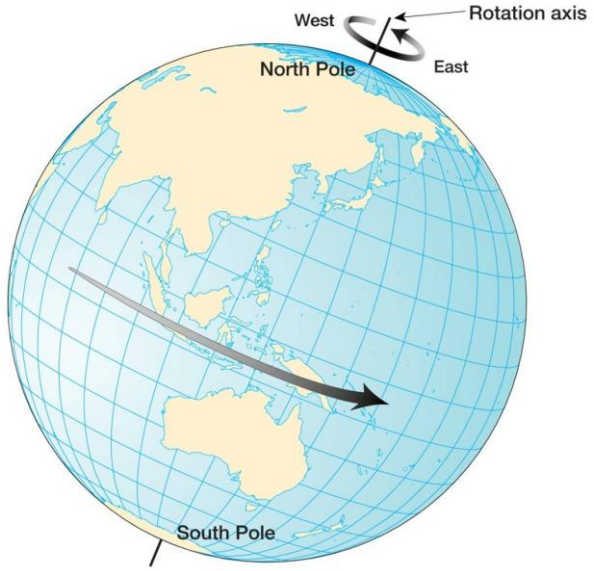



International Services Support Space Geodesy Research

- CDDIS began operations as the data system supporting NASA's Crustal Dynamics Project in 1982
- CDP paved the way for international cooperation in Space Geodesy
- By late 1980's, government agencies, universities, etc. began deploying GPS receivers in permanent configurations for scientific study
- Problem: No single government/agency/group could do the job on a global scale





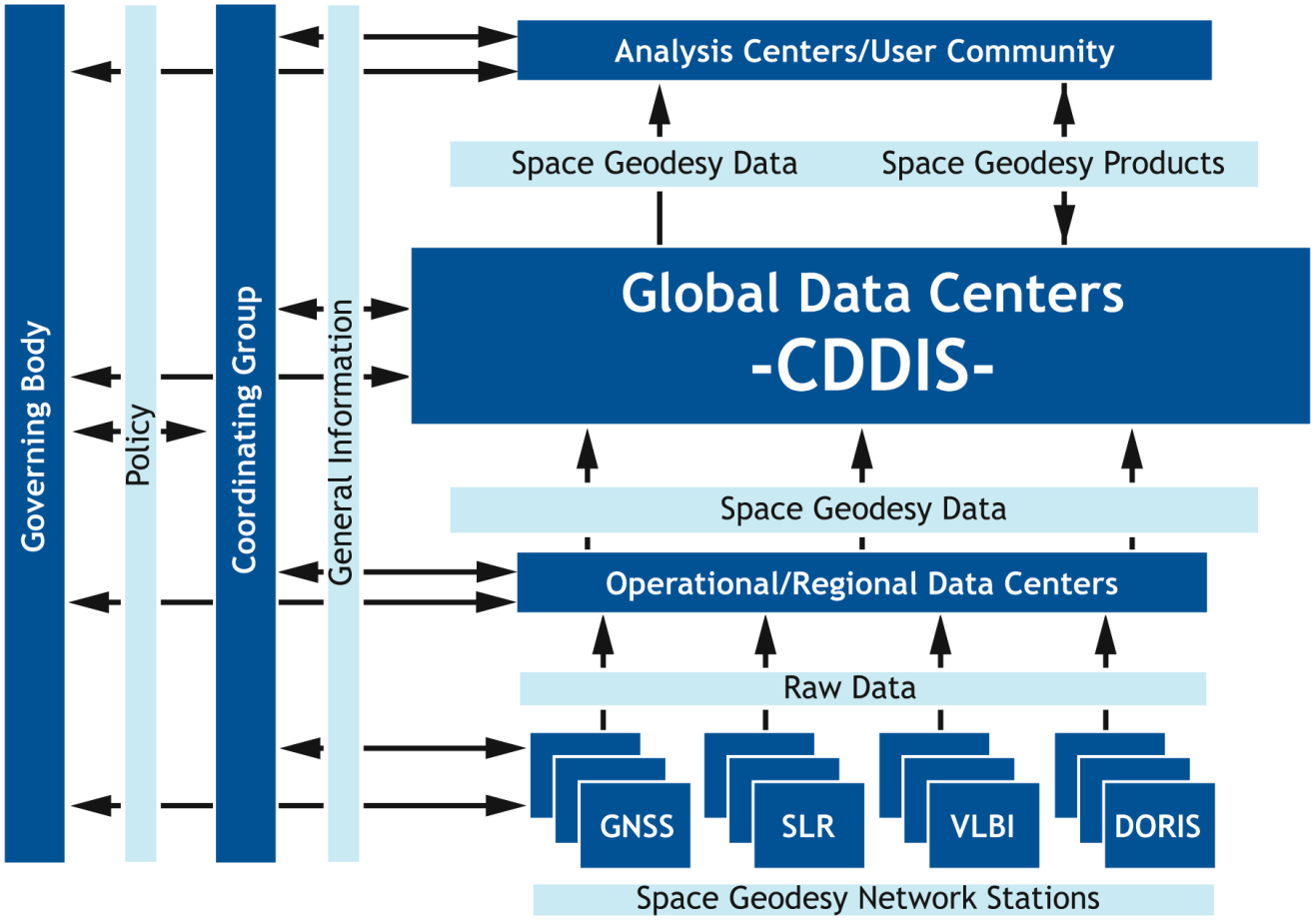


Paul Lowman/GSFC
http://denali.gsfc.nasa.gov/research/lowman/lowman.html

International Services Support Space Geodesy Research

- Solution: international, cooperative partnerships to facilitate research
- Multi-level cooperation: networks, data centers, analysis groups
- The International Association of Geodesy (IAG) established “services” to facilitate international cooperation
  - International GNSS Service (IGS)
  - International Laser Ranging Service (ILRS)
  - International VLBI Service for Geodesy and Astrometry (IVS)
  - International DORIS Service (IDS)
- 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
- Successful operation through cooperation of many international organizations who leverage their respective limited resources to all levels of service functionality

Data/Products: From Source to User



- CDDIS is THE principle data center supporting ALL geometric services created under the IAG
- Simplicity has been the key to success!

Archive Contents

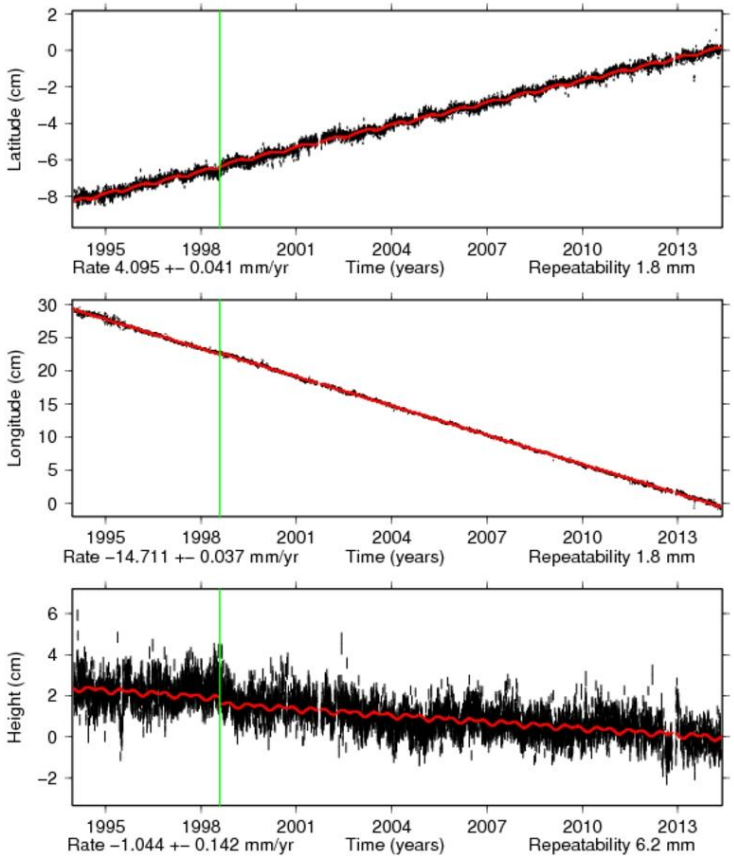
- Data:
  - Stations in the GNSS, SLR/LLR, VLBI, and DORIS networks generate point data on a multi-day, daily, hourly, and/or sub-hourly basis
    - GNSS: 500+ sites tracking GPS, GLONASS, and new GNSS (Galileo, QZSS, Beidou, IRNSS)
    - Laser Ranging (SLR and LLR): ~40 sites tracking 60+ satellites (including the Moon)
    - VLBI: 45 sites
    - DORIS: 58 sites tracking 5 satellites

- Metadata information:
  - Non-standard metadata, data type specific
  - Extracted from incoming files
  - Internal access to metadata database

Archive Contents

- Derived data (products):
  - Precise network station positions (for the International Terrestrial Reference Frame, ITRF)
  - Satellite orbits (for precise orbit determination, POD)
  - Station and satellite clocks (for timing)
  - Earth rotation parameters
  - Positions of celestial objects (for Celestial Reference Frame, CRF)
  - Atmospheric parameters (Ionosphere total electron content/TEC, and Troposphere zenith path delay/ZPD)

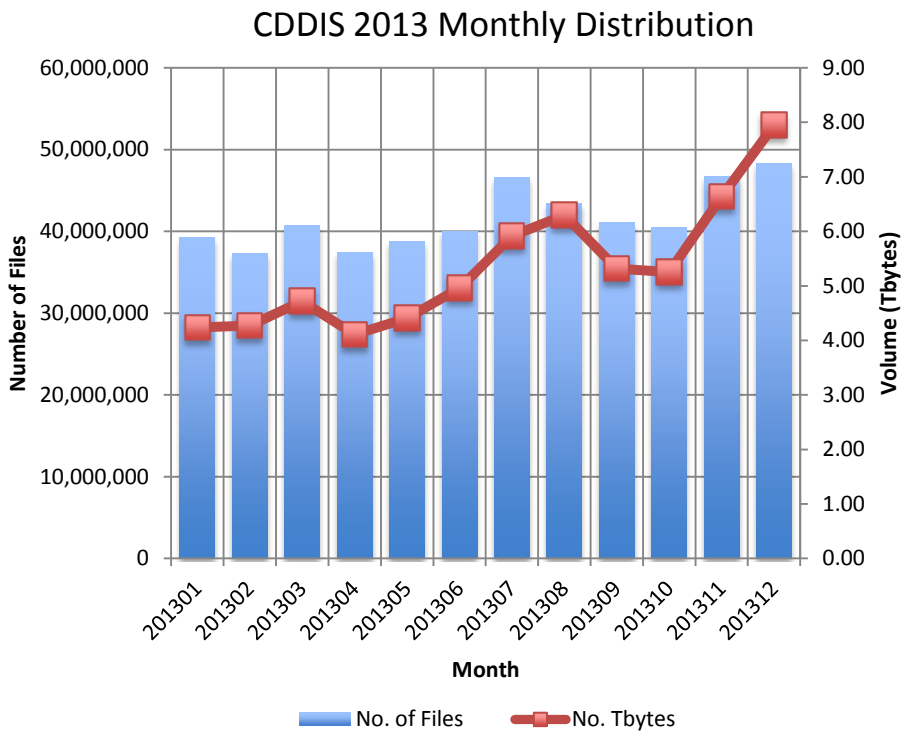
Time Series of Station Coordinates for Greenbelt, MD GNSS Station



Mike Heflin/JPL
http://sideshow.jpl.nasa.gov/post/series.html

Archive Usage

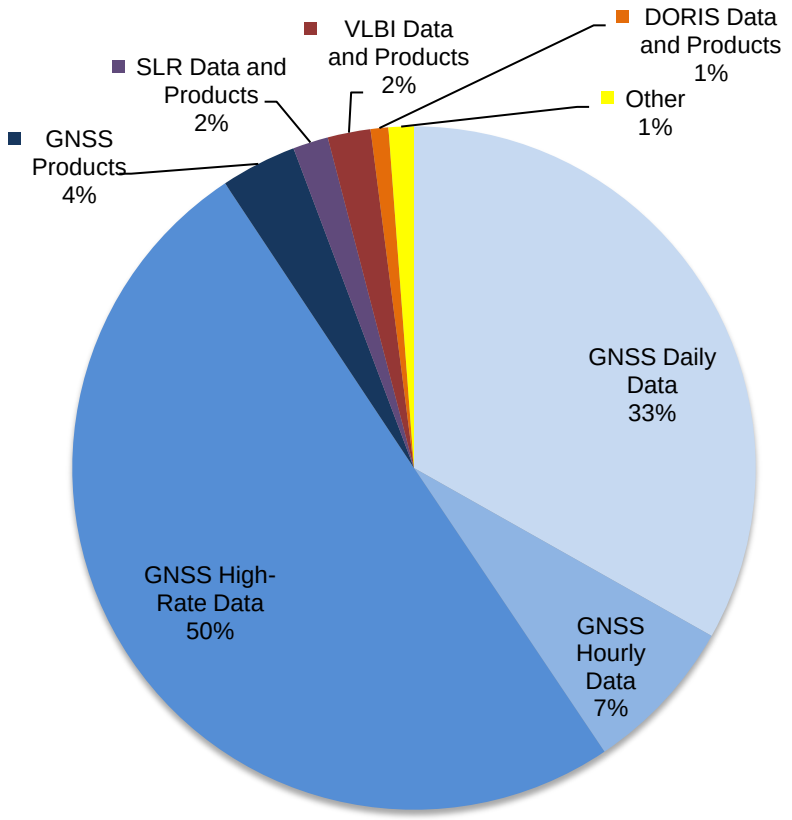
- Data and derived products from over 1500 sites in 1000 worldwide locations
- Archive updated with new files on varying time scales
- User access through anonymous ftp and web
- Utilize automated scripts executed on pre-defined schedules
- Other data centers download files to equalize data holdings
- Analysts are familiar with the structure of the online archive and thus know what files they require, their availability schedule, and where to find them



Archive Statistics

- File size is typically <2Mb/data “granule”, <10Mb/derived product “granule”
- Archive size: ~8.1Tb
- Ingest rate: ~5Gb (60K files)/day
- Distribution rate: ~240Gb (~2.4M files)/day
- Data (L1), products (L2) derived from these data, and information about data and products
- Multi-day, daily, hourly, sub-hourly
- Varying latencies (minutes, hours, days)

Archive Contents



Supported Groups and Missions (a subset!)

International Services

Missions

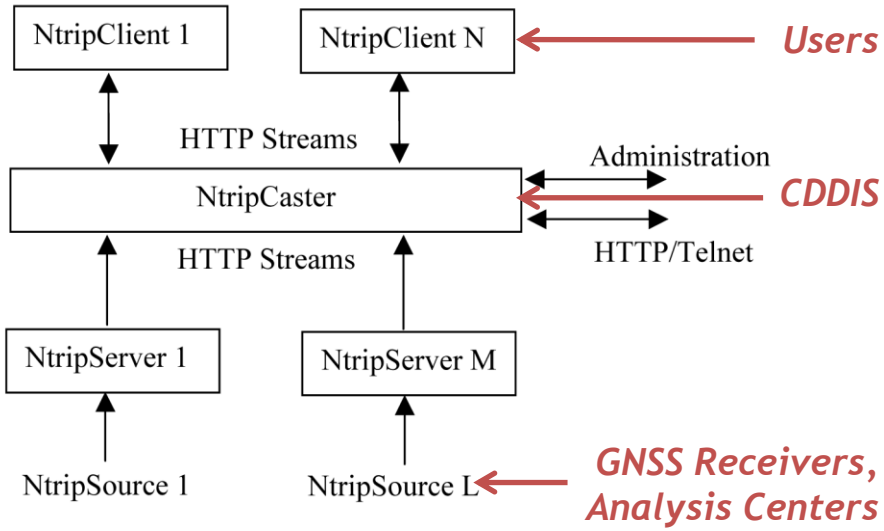
Agencies and Universities

Future Plans

- New capabilities: IGS Real-Time Service (RTS)
- Archive updates: Multi-GNSS Experiment (MGEX)
- Application development: Data discovery

Future Plans: Real-Time Data

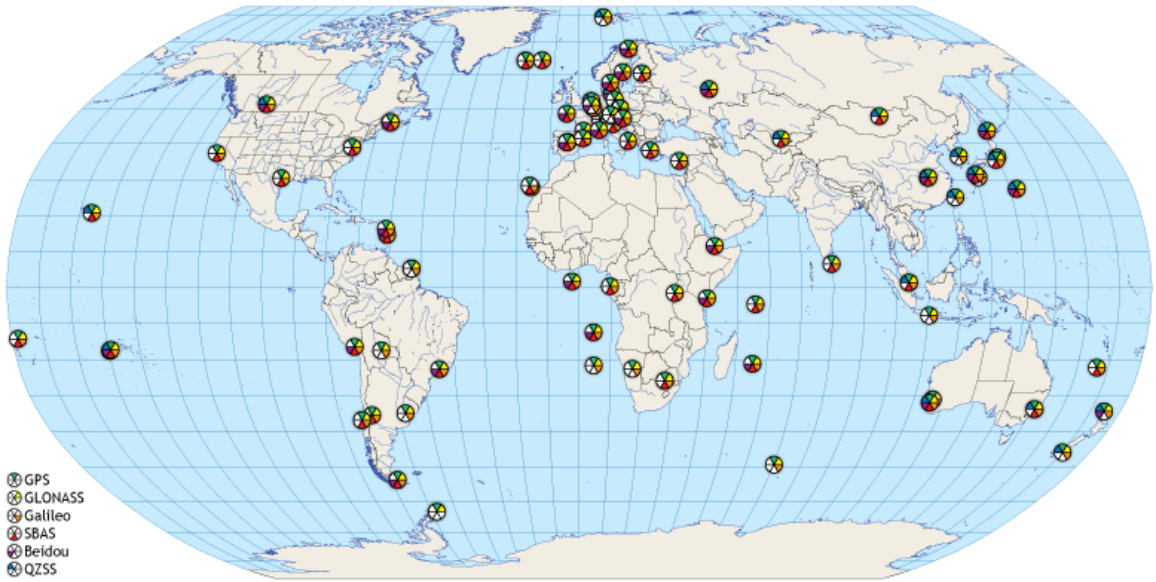
- Networked Transport of RTCM via Internet Protocol (NTRIP)
- Disseminates differential correction data or other kinds of GNSS streaming data to stationary or mobile users over the Internet
- Mobile users obtain corrections/data from reference stations in real-time to improve positioning
- CDDIS has installed an NTRIP broadcast relay (NtripCaster) to support the activities of the IGS Real-Time Service
- Capture streams for archive



- NtripSource: generates data streams at a specific location
- NtripServer: transfers the data streams from a source to the NtripCaster
- NtripCaster: major system component
- NtripClient: accesses data streams of desired NtripSources on the NtripCaster

IGS MGEX

- International GNSS Service Multi-GNSS Experiment
- Established by the IGS to track, collect, and analyze all available GNSS signals.
- IGS MGEX testing existing IGS infrastructure to handle operations of other GNSS (Galileo, Beidou, etc.)
- CDDIS expanded archive to include data from participating multi-GNSS receivers, products derived from the analysis of these data, and any required metadata for the experiment
- Archive now contains daily, hourly, and sub-hourly data from an additional 100+ stations
- Required introduction of new data format and software for data QC and metadata extraction



Future Plans: Data Discovery Application

- Completing development of new web-based application to aid users in data discovery, both within the current community and beyond
- To enable this data discovery application, the CDDIS is currently implementing modifications to the metadata extracted from incoming data and product files pushed to its archive

For More Information

- CDDIS website: *http://cddis.gsfc.nasa.gov*
- Noll, Carey E., The Crustal Dynamics Data Information System: A resource to support scientific analysis using space geodesy, Advances in Space Research, Volume 45, Issue 12, 15 June 2010, Pages 1421-1440, ISSN 0273-1177, http://dx.doi.org/10.1016/j.asr.2010.01.018.
- Contact:
  - Carey Noll
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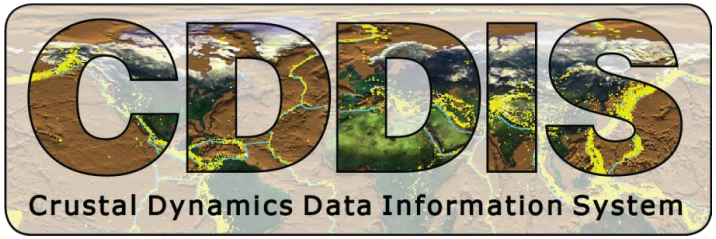
  - Lori Tyahla
    User services
    Ltyahla@sgt-inc.com
- Related websites:
  - IGS Website: *http://www.igs.org*
  - ILRS Website: *http://ilrs.gsfc.nasa.gov*
  - IVS Website: *http://ivscc.gsfc.nasa.gov*
  - IDS Website: *http://www.ids-doris.org*
  - GGOS Website: *http://www.ggos.org*
  - Space Geodesy Project Website: *http://space-geodesy.nasa.gov*



CDDIS Staff

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- Patrick Michael, Deputy Manager
- Maury Dube, Operations Lead
- Rebecca Limbacher, Operations
- Nathan Pollack, Applications Development
- Lori Tyahla, User Services, Webmaster