G43A-1023 Recent Developments at the CDDIS in Support of GGOS

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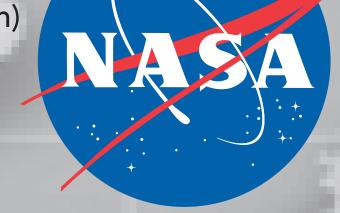NASA Goddard Space Flight Center
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Abstract: The Crustal Dynamics Data Information System (CDDIS) supports data archiving and distribution activities for the space geodesy and geodynamics community. The main objectives of the system are to store space geodesy and geodynamics related data and products in a central data bank, to maintain information about the archival of these data, to disseminate these data and information in a timely manner to a global scientific research community and provide user based tools for the exploration and use of the archive. The CDDIS data system and its archive is a key component in several of the operational services within the International Association of Geodesy (IAG) and its observing system, the Global Geodetic Observing System (GGOS), including the IGS, the International DORIS Service (IDS), the International Laser Ranging Service (ILRS), the International VLBI Service for Geodesy and Astrometry (IVS), and the International Earth Rotation and Reference Systems Service (IERS). In early 2015, CDDIS enhanced its operations with a new search tool enabling users to quickly search the archives in both spatial and temporal parameters. Also, in partnership with the IGS Real Time Service, CDDIS established a new GNSS real-time streaming service with over 150 data streams and 30 products streams to the GNSS community providing additional capability and redundancy to the IGS Real Time Service (RTS). This poster will showcase these enhancements and others that CDDIS has made over the past year for the geodetic community and describe future plans for the system.
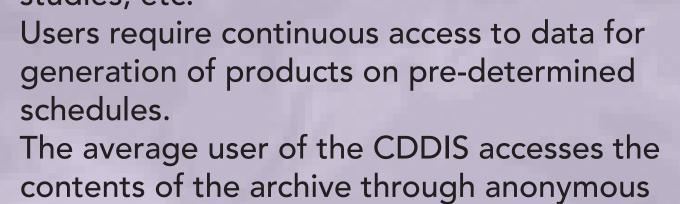
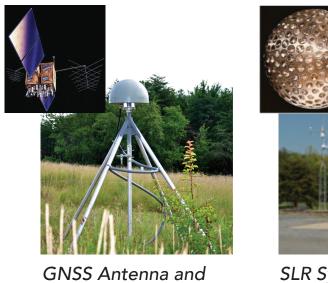## The Crustal Dynamics Data Information System (CDDIS)

Background:
- The Crustal Dynamics Data Information System (CDDIS) is NASA's active archive of space geodesy data, products, and information (Global Navigation Satellite System/GNSS, Satellite Laser Ranging/SLR, Very Long Baseline Interferometry/VLBI, and Doppler Orbitography and Radio-positioning Integrated by Satellite/DORIS).
- The CDDIS is one of 12 Earth Observing System Data and Information System (EOSDIS) Distributed Active Archive Centers (DAACs), which provides end-to-end capabilities for managing NASA's Earth science data.
- The CDDIS is funded by NASA/EOSDIS but cooperates extensively with the international community.
- The largest CDDIS user community comes from the services within the International Association of Geodesy (IAG).
- The contents of the CDDIS archive are utilized for geodetic studies, e.g., plate tectonics, earthquake displacements, Earth orientation, Earth's surface deformation, Earth's gravity field, etc.
- The CDDIS archive also plays an interdisciplinary role in supporting the derivation of a Terrestrial Reference Frame (the foundation for virtually all airborne, space-based and ground-based Earth observations), precise orbit determination (POD) for NASA/international missions, atmospheric studies, etc.
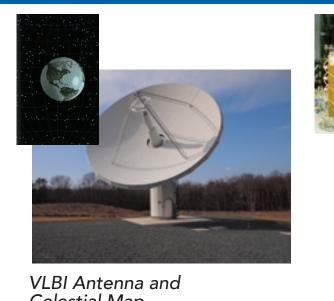- Users require continuous access to data for generation of products on pre-determined schedules.
- The average user of the CDDIS accesses the contents of the archive through anonymous ftp by means of automated scripts executed on predefined schedules (typically sub-daily).

GNSS Antenna and Satellite   SLR System and Target Satellite   VLBI Antenna and Celestial Map   DORIS Beacon and Satellite Receiver

Systems located at NASA Goddard Space Flight Center, Greenbelt MD

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: 530+ sites tracking GPS, GLONASS, and new GNSS (Galileo, Beidou, QZSS, IRNSS)
  + Laser Ranging (SLR and LLR): ~40 sites tracking 80+ satellites (including the Moon)
  + VLBI: 45 sites
  + DORIS: 58 sites tracking 5 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) …
- Metadata information:
  + Non-standard metadata, data type specific
  + Extracted from incoming files
  + Internal access to metadata database

Current Space Geodesy Site Locations

Archive Statistics:
- Total CDDIS archive size: ~12+ Tbytes and 130 million files
- Ingest rate: ~8.5 Gbytes (75K files)/day; 3 Tbytes/25.5 million files in FY2015
- Distribution rate: ~500 Gbytes (~4 million files)/day; 115 Tbytes/1.1 billion files in FY2015
- Data (L1, L1B), products (L2) derived from these data, and information about data and products
- Multi-day, daily, hourly, sub-hourly
- File size is typically <2 Mbytes/data "granule", <10 Mbytes/derived product "granule"
- Varying latencies (minutes, hours, days)
- CDDIS contains data and derived products from over 1500 observing sites located at about 1000 locations around the world, going back in time as far as 1975
- Archive is updated with new data/product files on varying time scales, dependent on the data type, from a sub-daily basis to weekly basis

The CDDIS and the IAG
- CDDIS is the principle data center for the geometric supporting services created under the umbrella of 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)
- These services function as cooperating federations dedicated to a particular type of data (e.g., GNSS, SLR, VLBI, or DORIS).
- The services provide data and products on an operational basis to geodesy analysts as well as a broader scientific community and are examples of a successful model of community management.
- Successful operation through cooperation of many international organizations who leverage their respective limited resources to all levels of service functionality.
- The CDDIS user community primarily consists of analysts supporting the services within the International Association of Geodesy.
- These groups produce derived products (e.g., positions of observing stations, Earth orientation parameters, precise satellite orbits, etc.) for use by a broader scientific community.
- The CDDIS has extensive partnerships through the IAG serving as one of the primary data centers for the geometric services and its observing system, GGOS (Global Geodetic Observing System).

Breakdown of CDDIS Archive Contents

CDDIS Data Discovery Application

Background:
- A web application, the CDDIS Archive Explorer, was recently developed and implemented on the CDDIS website to display data holdings to aid in discovering data available through the CDDIS
- The application allows users to enter spatial, temporal, target, or site identification parameters to determine sites of interest

Use Cases:
- 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, latitude/longitude, range
  + Target: Satellite (SLR, DORIS)
  + Designation: Station name/number/code/DOMES number

Results:
- Map of sites satisfying specifications
- List of sites satisfying specifications
- List of data holdings satisfying specifications
- Metadata relevant to selection
- Site log for site selection

Next Steps in Application Development:
- Include additional query options (by target, by site identifier)
- Include links to data holdings for download

The initial page of the data discovery application displays a list of system types (GNSS, SLR, DORIS, VLBI), a temporal specification window to allow the user to specify date range, and a map window to allow the user to enter spatial subsetting through a map interface bounding box or through coordinate specifications.

In this example, the user specifies a query for GNSS daily data holdings in the Australia/New Zealand region for October 2015.

The resulting page shows two sections:
- *A map of sites satisfying the spatial subset and temporal bounds*
- *The corresponding list of sites satisfying these bounds*

Continuing this example, the user then selects a specific site (View button), Auckland (AUCK), to see additional information. The map highlights the location of the site and the page expands to display more information from the IGS site log (GNSS receiver information) for the AUCK GNSS site.

CDDIS Real-Time Activities

Background:
- The IGS Real-time Service (RTS) is a GNSS orbit and clock correction service that enables precise point positioning (PPP) and related applications, such as time synchronization and disaster monitoring, at global scales for scientific and hazard detection applications
- RTS based on the existing IGS global infrastructure of network stations, data centers, and analysis centers that provide world standard high-precision GNSS data products
- Real-time stations disseminate differential correction data or other kinds of GNSS streaming data to stationary or mobile users over the Internet
- Users capture data streams for applications requiring real-time corrections and for generation of real-time products
- Users obtain corrections/data from reference stations in real-time to improve positioning

Real-Time GNSS Network (available from CDDIS)

Real-time GNSS at CDDIS:
- In early 2015, the CDDIS real-time GNSS service became operational
- Network Transport of RTCM via Internet Protocol (Ntrip) software used to transmit real-time GNSS data and derived product "streams" through the CDDIS "caster"
- This "caster" is an http server which both receives and transmits RTCM streams to/from Ntrip servers and Ntrip clients
- Thus far, CDDIS makes streams available from 160 globally distributed real-time GNSS receivers and 37 derived product streams:
  + GNSS data (1-second)
  + GNSS orbit corrections (5 or 60-seconds)
  + GNSS clock corrections (5 seconds)
  + Ionosphere VTEC (vertical total electron content)
- CDDIS caster is one of three primary systems supporting the IGS Real-Time Service
- A username/password is required to access streams
- CDDIS developed an interface to an EOSDIS system for user registration

Caster User Registration/Sign-on:
- Users of IGS RTS casters, including the CDDIS caster, must register and utilize a username/password for access
- CDDIS has access to a world-class user registration process from EOSDIS, which currently has over 100,000+ users in its system
- CDDIS developed software to interface its Ntrip caster with the EOSDIS user registration system (URS)
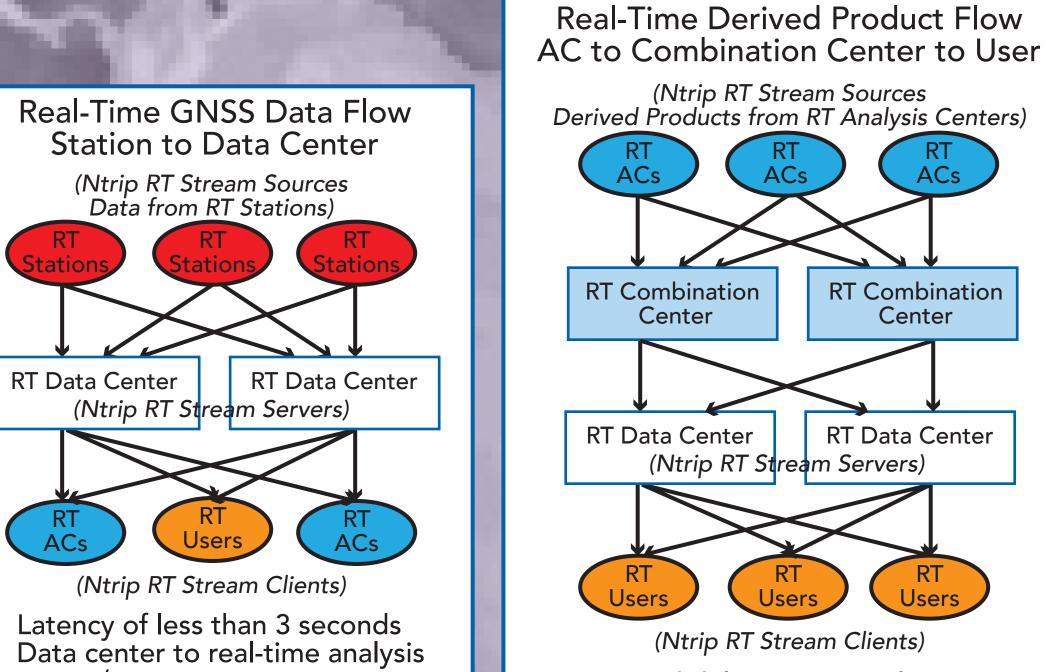- Registration process is accomplished in near real-time
- Once registered within the EOSDIS system, the user has access to the entire suite of EOSDIS products across all 12 EOSDIS DAACs
- Over 50 users have registered for access since the start of the CDDIS real-time service

Process:
- User accesses the registration form on the CDDIS caster website and completes the form with the required information
- User submits the form and an email is generated with a validation link; user clicks on the link within the email and the URS system validates the form data
- CDDIS staff grant the user access to CDDIS caster; typical 24 hour turn around on full registration process
- User now has access to the caster as well as other EOSDIS data center applications

Real-Time GNSS Data Flow Station to Data Center
(Ntrip RT Stream Sources Data from RT Stations)
RT Stations → RT Data Center (Ntrip RT Stream Servers) → RT ACs (Ntrip RT Stream Clients)
- Latency of less than 3 seconds
- Data center to real-time analysis center/user

Real-Time Derived Product Flow AC to Combination Center to User
(Ntrip RT Stream Sources Derived Products from RT Analysis Centers)
RT ACs → RT Combination Center → RT Data Center (Ntrip RT Stream Servers) → RT Users (Ntrip RT Stream Clients)
- 5 second delay to accumulate streams at DC; 5 seconds to produce orbits and clocks
- Ideal delay of 10 seconds to CCs
- Products delivered every 5 seconds

Real-Time User Applications

Real-Time User Affiliations

Academic research is the largest application area for CDDIS real-time users.

The majority of CDDIS real-time users are from education, commercial, & government organizations.

CDDIS System and Operations Improvements

Background
- As NASA's archive of space geodesy data, CDDIS is well known throughout many scientific communities
- Use of CDDIS has soared over the past several years: in 2015 over 1.2 billion downloads of data were accomplished through ftp alone
- Growth in the scientific importance of CDDIS, as well as new activities (e.g., real-time GNSS), has required improvements in system architecture to support both current and expected new demands
- As an EOSDIS DAAC, CDDIS must enact policies and procedures as part of a larger EOSDIS community

New Hardware
- CDDIS moving all operations within the EOSDIS IT and physical environment, including two complete operations centers in separate locations at GSFC for operations and disaster recovery
- Complete new unified storage system with over 100TB in both operations and disaster recovery locations; easily upgradeable without down-time
- New database cluster system with over 6TB of RAID 10 storage
- Dual redundant 40Gb Ethernet connections direct to the Internet backbone
- Leveraging the significant resources of the EOSDIS community

Significant Improvement in Operations
- Near-future enhancements:
  + Implementation of single sign-on capability for upload process
    - Uses EOSDIS Earthdata Login
    - Ties into the 11 other EOSDIS DAACs
  + Addition of real-time streams from the JPL Global Differential GPS (GDGPS) project
- Mid to late FY2016 enhancements:
  + Metadata available through EOSDIS Common Metadata Repository (CMR) for improved search capabilities at CDDIS and EOSDIS partners
  + Conversion of GNSS real-time streams to high-rate data files for archive
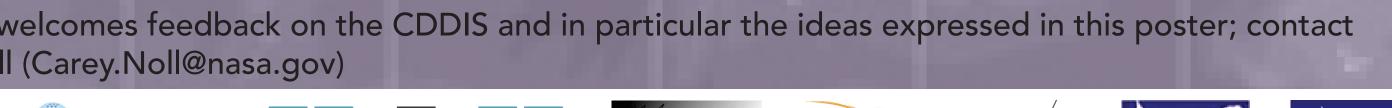
New CDDIS File Upload Operations
- Will go into effect with operations in late winter/early spring 2016
- HTTP-based protocol => upload through ftp will no longer be supported!
- Uses EOSDIS Earthdata login process
- Requires all data providers to register with EOSDIS for a user account
- Has both web and command line availability
- Allows for scripting with cURL and other user options
- Eliminates the two-port problem with ftp and firewalls

Data providers must obtain and specify EOSDIS Earthdata login credentials to upload files to CDDIS.

Data providers can use http to specify type of data and list of files to be uploaded.

More Information/Feedback:
- Data and products are acquired as part of NASA's Earth Science Data Systems and archived and distributed by the Crustal Dynamics Data Information System (CDDIS):
- C. Noll, 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, DOI: 10.1016/j.asr.2010.01.018.
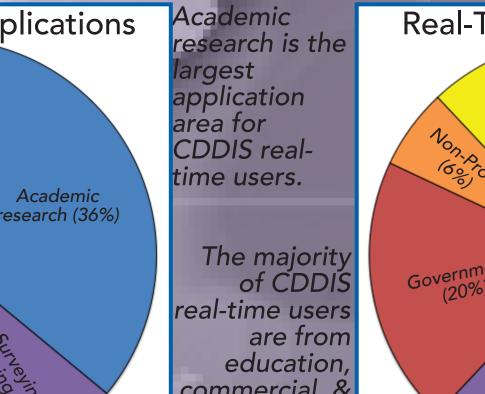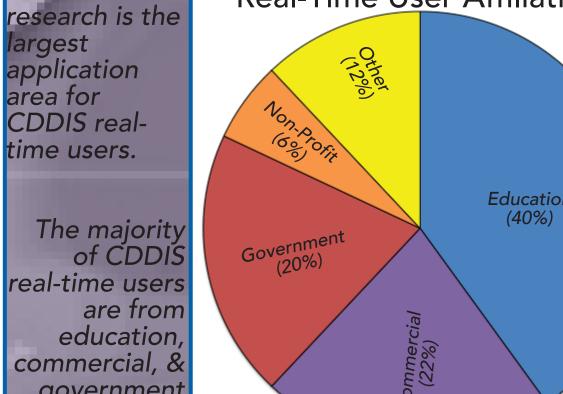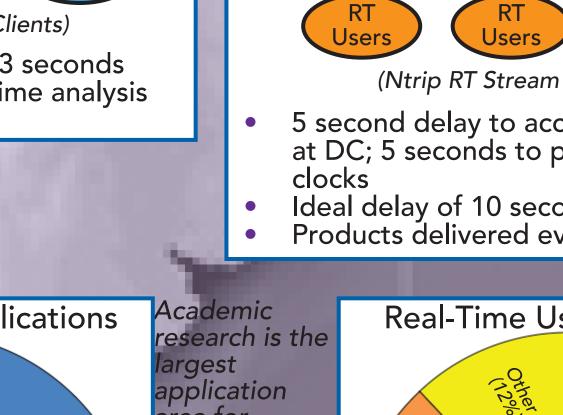- The staff welcomes feedback on the CDDIS and in particular the ideas expressed in this poster; contact Carey Noll (Carey.Noll@nasa.gov)
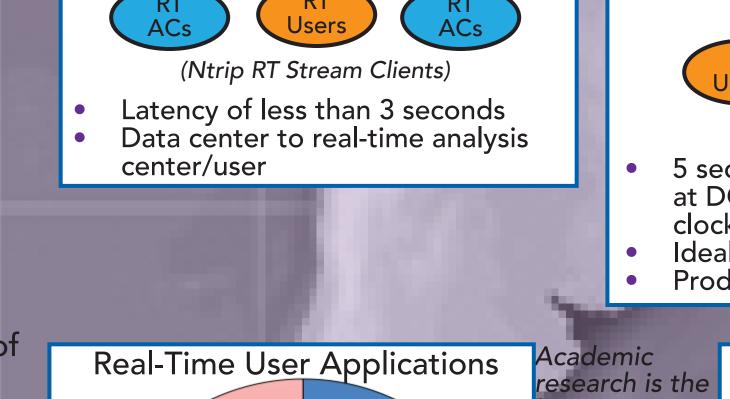

Crustal Dynamics Data Information System