Enabling Discoveries in Multiscale Earth System Dynamics: Geodetic Facility for the Advancement of Geoscience (GAGE)

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The GAGE Facility, operated by UNAVCO, provides geodetic infrastructure, data services, and education and community engagement support for NSF, NASA and community research projects and investigators.

This annual report summarizes Year 2 activities, performance metrics and broader impacts from NSF Cooperative Agreement EAR-1724794, “Enabling Discoveries in Multiscale Earth System Dynamics: Geodetic Facility for the Advancement of Geoscience (GAGE).” This Cooperative Agreement includes Cooperative Support Agreements EAR-1851159, EAR-1851163 and EAR-1851169.

This report includes three sections:
- CSA EAR–1851159 activities (EAR)
- CSA EAR–1851163 activities (OPP)
- CSA EAR–1851169 activities (NASA)

Supplemented by six appendices:
- A. List of EAR projects and continuous networks supported
- B. List of OPP projects and continuous networks supported
- C. Subaward monitoring report for CWU
- D. Subaward monitoring report for MIT
- E. Award administration
- F. Advisory Committee meeting notes

And two supporting files:
- List of publications
- List of collaborators

Report format notes: The WBS-element number is provided for each activity; WBS-element numbers may not be sequential if activities are in different CSAs. Activities and associated metrics are color-coded by sensor/data type throughout the report; e.g., GNSS activities and metrics are always dark red, SAR is always dark blue, etc. The metrics tables provide a rolling summary of the most recent quarters to facilitate the identification of potential trends; values from previously reported quarters may be updated as new information becomes available. Some metrics from EAR–1261833 have been carried forward into EAR–1724794 to provide continuity of reporting.
President’s Summary

Over the past award year, the GAGE Facility activities have supported scientific advances in diverse disciplines across the earth and environmental sciences. This research support takes many forms, from high rate and real-time data access to instrument loans for experiments all over the planet to customized data products, software development, and specialized engineering. Notable examples include high-rate and real-time GNSS streams that capture both the static and dynamic displacements of the Earth’s surface during and after large earthquakes, collaborative multi-sensor deployments to decipher the changing state of the Thwaites Glacier region in Antarctica, long observation time series that enable measurements of changing seasonal and decadal hydrologic mass loads, and high-resolution images of surface changes that can quantify the rates of surface processes. As GAGE’s data holdings extend over time and improve in resolution, these observational gains are translated into novel discoveries across wider and wider ranges of scale in both length and time. The persistence of instrumental networks and the high quality of data returned are both requisite for new science and demanding of excellence in technical operations.

GAGE activities also support scientific applications that improve the resilience and sustainability of human communities. Scientific research doesn’t simply expand our understanding of our world; it also empowers us to live better. For example, displacements during and after large earthquakes are now routinely used to evaluate time-dependent changes to earthquake hazards in surrounding regions and to help high-risk communities to be better prepared. Emerging hydrogeodetic tools have great potential to improve seasonal estimates of water availability, so that water can be stored and used as efficiently as possible to mitigate impacts to municipalities and communities. High-rate and real-time displacement observations paired with machine learning offer the possibility of enhancing existing earthquake early warning and response systems, and advanced imagery analyses improve disaster response. GAGE infrastructure and products support research into autonomous vehicles, neural networks, and space weather, far beyond traditional Earth science domains.

Finally, GAGE helps to build a strong foundation for future discoveries by investing in diverse young scientists, sharing state-of-the-art tools and techniques, and maintaining scientific infrastructure. Workforce development, training, and teaching activities ensure that as many people as possible have equal access to the instruments, data, and analysis tools that they need to make discoveries, regardless of where and how they work. In addition to our community university faculty, GAGE resources are used by schoolchildren, teachers, citizen scientists, and professional surveyors.

The future of geodesy is bright. Lengthening time series and improving sensor resolution continue to provide constraints on new and smaller signals. New initiatives for multi-sensor, multi-data interdisciplinary research, data handling, education and outreach, and sensor hardening should facilitate new science. We can’t wait to see what the next year reveals about our dynamic planet.
### GAGE Facility Summary Metrics

<table>
<thead>
<tr>
<th>Program</th>
<th>Metric</th>
<th>Target (Q4Y1 -Q3Y2)</th>
<th>Passed?</th>
</tr>
</thead>
<tbody>
<tr>
<td>EAR Networks</td>
<td>NOTA cGNSS network data return*</td>
<td>85%  89%</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>NOTA cGNSS network uptime**</td>
<td>85%  85%</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Borehole seismic data return*</td>
<td>85%  93%</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Borehole strainmeter data return*</td>
<td>85%  90%</td>
<td>Yes</td>
</tr>
<tr>
<td>EAR Instruments</td>
<td>GNSS instruments in pool (&lt;5 years old)</td>
<td>50  53</td>
<td>No</td>
</tr>
<tr>
<td>OPP Networks</td>
<td>ANET cGNSS network data return*</td>
<td>85%  87%</td>
<td>Yes</td>
</tr>
<tr>
<td>OPP Instruments</td>
<td>Arctic GNSS instruments in pool (&lt;5 years old)</td>
<td>30  12</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Antarctic GNSS instruments in pool (&lt;5 years old)</td>
<td>30  14</td>
<td>No</td>
</tr>
<tr>
<td>NASA GGN</td>
<td>Global GNSS Network data return*</td>
<td>85%  94%</td>
<td>Yes</td>
</tr>
<tr>
<td>Data Services</td>
<td>Data Center accessibility**</td>
<td>98%  100%</td>
<td>Yes</td>
</tr>
<tr>
<td>ECE</td>
<td>EWO Activities***</td>
<td>55  74</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Individuals Reached****</td>
<td>1,500 6466</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Percentage of data received versus expected.

**Percentage of successful results from total attempts to access GNSS Level 1 data files via FTP.

***Annual target is 55 with ~12-15 activities quarterly.

****Annual target is 1,500 individuals per year with quarterly totals ranging from 300 - 500.
GAGE Science Snapshot #1

Snapshots of scientific discoveries from the GAGE research community are posted on the UNAVCO website. The following Snapshot was posted on 25 February 2020.

Rapid Geodetic Assessment of July 2019 Ridgecrest, California Earthquakes


Summary: The July 2019 moment magnitude 6.4 and 7.1 Ridgecrest California earthquakes occurred approximately 34 hours apart on connected strike-slip faults. Continuous and temporary Global Navigation Satellite Systems (GNSS) captured the surface motions during and after the events. In particular, temporary GNSS sites installed near the epicenter of the first earthquake (M6.4) recorded the surface motions of the second, larger M7.1 event. The geodetic data provides crucial information about how the faults move during and after an earthquake and how this motion is related to other processes, such as plate tectonics and fault creep.

The background plate tectonic motion of the GNSS sites was estimated from continuously measuring GNSS sites and previous temporary GNSS campaigns. The surface motions for the M6.4 earthquake consisted of a left-lateral rupture with the closest observed surface displacements of 3 and 11 centimeters. The M7.1 event was a right-lateral rupture with the largest recorded displacement of 80 centimeters. The faults are connected and the M6.4 earthquake triggered the M7.1 event. The results provide important details about the earthquake process in the eastern California shear zone and can be compared to other observations before, during, and after these events.
GAGE Science Snapshot #2

Snapshots of scientific discoveries from the GAGE research community are posted on the UNAVCO website. The following Snapshot was posted on 16 March 2020.

**GNSS Networks in the Americas to Study Earth and Atmospheric Processes**


**Summary:** Global Navigation Satellite Systems (GNSS) networks in the Americas provide useful observations of Earth processes and help with earthquake, volcano, tsunami and other hazard preparedness, response and mitigation. The networks consist of thousands of ground-based sites that provide high precision measurements of Earth motions and atmospheric conditions, in real time or through daily download. As receiver technology advances and more satellites are available for tracking, the GNSS observations will grow in value for research, hazard risk reduction, resource management, navigation, timing, surveying and other applications.

Today, UNAVCO with the support of the National Science Foundation operates the Network of the Americas (NOTA) with over a thousand sites in the U.S., Mexico, the Caribbean and some other regions in the Americas. These networks are being enhanced over time, so that many sites operate in real time for hazard risk reduction and many receivers are fully GNSS capable for more and better observations.

Regional GNSS networks have resolved aseismic fault slip, constrained earthquake slip estimates, tracked crustal deformation, enhanced our understanding of earthquake and volcano processes, and constrained the crustal deformation caused by earthquakes and other Earth processes. Real time GNSS measurements are advancing hazard mitigation by enhancing warnings about earthquakes, volcanic unrest, tsunamis and landslides. The continuous sensing of the atmosphere via GNSS allows for measurements of the electron content in the ionosphere and precipitable water vapor in the troposphere. Such real time GNSS measurements in the atmosphere can be used to forecast solar storms, severe weather, hurricane paths and wildfire potential.

(a) Diagram of typical Network of the Americas (NOTA) permanent Global Navigation Satellite System (GNSS) site configuration.
(b) Drilled and braced antenna monument with GNSS antenna.
(c) Additional components of this installation include an enclosure for GNSS receiver and communications and power devices, solar panels, and a meteorological instrumentation package. (Image credit: UNAVCO)
GAGE Science Snapshot

Snapshots of scientific discoveries from the GAGE research community are posted on the UNAVCO website. The following Snapshot was posted on 17 September 2019.

**Determining Watershed-Scale Hydrologic Loading with GPS**


**Summary:** Vertical surface motions measured by Global Positioning System (GPS) sites in Idaho, Montana, Nevada and Wyoming can be combined to measure water load over local to regional scales that is useful for water resource management and our understanding of the water cycle. This innovative technique provides information at a scale that satellite data or in situ point measurements cannot. Users can use this technique and the many available geodetic networks to track precipitation, water quantity changes, and the state of aquifers.

![study area location map](image)

Study area location map. GPS stations are represented with red circles and SNOTEL stations are represented with blue hexagons. Figure is courtesy of the author, Ellen Knappe.
GAGE Science Snapshot

Snapshots of scientific discoveries from the GAGE research community are posted on the UNAVCO website. The following Snapshot was posted on 13 April 2020.

**Caribbean Plate Tectonics Defined by Global Positioning System (GPS) Network**


**Summary:** A stable Caribbean reference frame 2018 (CARIB18) is developed for the Caribbean plate using long-term observations from 18 GPS stations along the margins of the plate. The results provide seven parameters for transforming positional time series from a global reference frame (IGS14) to a regional reference frame. CARIB18 is fundamental to study plate motions, earthquakes, volcanoes, landslides, the water cycle and other earth processes within the Caribbean region.

A stable regional reference frame for the Caribbean plate, called CARIB18, consists of seven parameters for converting positional time series from a global to a regional reference frame. In addition, the three-dimensional site-velocities of 250 GPS stations with respect to CARIB18 are defined. CARIB18 is stable at a level of 0.7 millimeters per year in the horizontal directions and 0.9 millimeters per year in the vertical direction. CARIB18 will be used to understand plate tectonics, earthquakes, volcanoes, landslides, the water cycle and other earth processes.
Geodetic Infrastructure

The GI program performs construction, operation and maintenance (O&M) of permanent networks of GNSS, borehole geophysics and other instruments; coordination and execution of PI campaign projects and support of NSF-funded PI networks; development and testing of instrumentation, monuments, power systems and communications; and logistical support of all field operations.

<table>
<thead>
<tr>
<th>GI NSF-EAR Key Metrics</th>
<th>Proposals/Projects Supported</th>
<th>Permanent Stations Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Period</td>
<td>NSF-EAR, NSF-Other</td>
<td>Non-NSF</td>
</tr>
<tr>
<td>2019 Jul-Sep</td>
<td>8</td>
<td>11</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>

Non-NSF projects/proposals/stations: synergistic community PI activities in which the PI is funded by non-NSF resources (NASA, university, etc.).

Total Permanent Stations operating as reported in Appendix A.

GI Advisory Committee (U1.1.1)

Y1Q4: The GI advisory committee (GI AC) was convened in person in Boulder at UNAVCO headquarters on September 12-13, 2019 as well as by Zoom for members of the GI AC that were unable to participate in person. GAGE Facility Program Director Dr. M. Benoit addressed the GI AC briefly, as she was visiting UNAVCO for other purposes. GI staff developed and presented updates for each WBS element within GI as part of the GAGE Facility. 13 presentations were made available along with additional background information as PDF files to the GI AC. Eight of nine GI AC members participated and all members of the GI AC reviewed and approved the 2019 GI AC report to the UNAVCO Board. The GI AC made 12 commendations and 12 recommendations in their report, which was presented to and approved by the UNAVCO Board on October 8, 2019. The GI AC report is available on the UNAVCO website.

Y2Q1: The GI AC report was presented to and approved by the UNAVCO Board on October 8, 2019, available on the UNAVCO website.

Y2Q2: The GI advisory committee (GI AC) was reconstituted by the UNAVCO BoD during Y2Q2. Elisabetta D’Anastasio and Diego Melgar have agreed to act as Joint Chairs. The GI AC will be called upon to review the documents requested by NSF for the upcoming GI program review in June 2020.

Y2Q3: The GI AC reviewed a draft of the 86 page document submitted on May 1, 2020, which answered 60 questions posed by NSF. Also, the GI AC reviewed the three presentations (aligned with the structure of the written report) to NSF for the joint IRIS IS and GI virtual program review that occurred June 22-24, 2020. Diego Melgar participated in the virtual panel.

GI Program & Personnel Management (U1.1.2)

Notable activities:

Y1Q4:
- Period of Public Comment on the NSF Dear Colleague Letter for NOTA Station Decommissioning came to an official close on Sep. 30, 2019 and was extended to Oct 31, 2019.
- NOTA Southwestern Regional office was successfully relocated in San Clemente, CA.
- Successful close-out of USGS ShakeAlert 2017-2019 Cooperative Agreement and associated Supplemental Funding. All project scope was completed on time and on budget.
- Supported 2019-07-06 M7.1 Ridgecrest, CA earthquake sequence response. Efforts allowed 100% data recovery from all proximal stations.

Y2Q1:
- Dr. D. Mann, UNAVCO project lead, convened a USGS ShakeAlert project team meeting on Dec. 11, 2019, concurrent to the AGU Fall meeting in San Francisco, CA. Comments about the future role of GNSS in ShakeAlert from Dr. B. Brooks, USGS emphasized that the NOTA RT-GNSS results from the Ridgecrest sequence "strengthened" the position of GNSS within the ShakeAlert system.

Y2Q2:
- NSF sought good faith commitments by 31 March 2020 from parties interested in adopting NOTA stations to be decommissioned. GI staff is actively
engaged in transferring station permits to the adopting institutions. To date, ~90 of the planned 128 NOTA stations to be decommissioned have garnered some interest from state and federal agencies.

- Two articles submitted in Y2Q1 were published in Seismological Research Letters: 1) Hodgkinson et al., 2020 - which focused on NOTA RT-GNSS determinations of earthquake magnitudes for 5 events, NOTA station earthquake detection sensitivity, and real-time calculations of earthquake magnitudes based on horizontal components of RT-GNSS data of Peak Ground Displacements; and 2) Mattioli et al., 2020 - which focused on the field and data response of the GAGE Facility along with an analysis of GNSS data related to the July 2019 Ridgecrest earthquake sequence.

Y2Q3:
- GI staff responded to 60 questions posed by NSF in preparation for the upcoming Joint IRIS-UNAVCO SAGE-GAGE IS and GI program review. Questions were organized into 4 sections. In response, UNAVCO prepared an 86 page, hyperlinked PDF document that was submitted on May 1, 2020.
- GI staff participated in a Virtual Joint Review of the IRIS SAGE IS and the UNAVCO GAGE GI Programs. Materials developed for the review included new PowerPoint templates along with all associated content for three presentations to the panel developed in partnership with ScienceMediaNL.

Issues/challenges:

Y1Q4:
- Open positions (EII/EIII level) within NOTA Northwest/AK region and Polar Services: The AK position went through a complete hiring cycle with no appointment. Applications for the Polar Services position remain under evaluation. For the Polar Services position remain under evaluation.
- NOTA stations need upgrades: Key components that must be replaced include aging and obsolete Trimble NetRS GPS-only receivers, narrow-band, GPS-only choke ring antenna LNAs, and cellular modems no longer will be supported by major cell carriers.

Y2Q1:
- Open positions (EII/EIII level) within NOTA Northwest/AK region and Polar Services: GI continues to struggle with successfully filling these positions.
- NOTA station upgrades.

Y2Q2:
- GI continues to struggle with successfully filling vacant engineering positions.
- NOTA station upgrades

Y2Q3:
- Open positions (EII/EIII level) within NOTA Northwest/AK region and Polar Services: One new hire in Polar Services was completed in Y2Q3, with Dr. Erika Schreiber, who recently completed her Ph.D. at CU, joining the team. GI still has three open engineering positions at the close of Y2Q3 with the departure of J. Galetzka, who left to join NOAA NGS.
- NOTA components requiring replacement: obsolete Trimble NetRS GPS-only receivers, narrow-band, GPS-only choke ring antenna LNAs, and obsolete cellular modems.

<table>
<thead>
<tr>
<th>GI Program Personnel Headcount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Period</td>
</tr>
<tr>
<td>2019 Jul-Sep</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
</tr>
</tbody>
</table>

Budgeted and Actual Headcounts include EAR, OPP, and NASA CSAs and other awards. Headcount includes individuals working non-GAGE projects and those individuals that cross-report to GDS and BA.

Permitting (U1.1.4)

<table>
<thead>
<tr>
<th>Permitting</th>
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</thead>
<tbody>
<tr>
<td>Time Period</td>
</tr>
<tr>
<td>2019 Jul-Sep</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
</tr>
</tbody>
</table>
Geodetic Infrastructure

NOTA GNSS

GNSS Network Operations (U1.2.1),
NOTA Federation and GNSS Modernization (U1.6.1)

GI supports the O&M of continuously operating GNSS stations located across the United States, Puerto Rico, Mexico, the eastern Caribbean, Central and northern South America as part of NOTA. GPS-only NOTA stations are being modernized with multi-constellation, state-of-the-art GNSS receivers and antennas to support GNSS tracking.


<table>
<thead>
<tr>
<th>Time Period</th>
<th>Stations Number</th>
<th>Station(s) Removed</th>
<th>Network Uptime (%)</th>
<th>Stations Modernized</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>1,277</td>
<td>1</td>
<td>In develop.</td>
<td>28</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>1,277</td>
<td>1</td>
<td>87%</td>
<td>43</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>1,277</td>
<td>0</td>
<td>85%</td>
<td>23</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>1,276</td>
<td>1*</td>
<td>82%</td>
<td>30</td>
</tr>
</tbody>
</table>

Uptime: % of stations that deliver data within 72 hours of collection. Modernized: site received upgraded power, communications, sensor and/or antenna.

*P369 will be removed in Y2Q4

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Engineer Days in Field</th>
<th>Site Visits</th>
<th>Issues Resolved</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>224</td>
<td>167</td>
<td>432</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>216</td>
<td>157</td>
<td>450</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>128</td>
<td>109</td>
<td>303</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>97</td>
<td>117</td>
<td>325</td>
</tr>
</tbody>
</table>

Notable activities:

Y1Q4:
- Supported 2019-07-06 M7.1 Ridgecrest, CA earthquake sequence response. Efforts allowed 100% data recovery from proximal stations.
- Completed helicopter work on Unimak Island, Akutan Island, and Mount St. Helens. Cost savings were gained with AVO joint operations.
- Completed ShakeAlert seismic colocation and station upgrades on schedule and within budget.
- Commenced NOTA station O&M in the Caribbean.
- Completed station and telemetry maintenance and modernization in and around Yellowstone NP.
- Station GERD, one of the four original CALIPSO Facility stations on Soufriere Hills volcano on Montserrat was decommissioned, reducing the number of NOTA GNSS stations to 1,277.
- Procured 290 Trimble NetR9 receiver codes for full GNSS constellation tracking.

Y2Q1:
- NOTA stations, GERD and P778, removed as requested by the respective landowners.
- Completed 6 station O&M in the Oaxaca, Mexico.
- Approximately 200 of the 290 Trimble NetR9 receiver codes for full GNSS constellation tracking were uploaded to deployed NOTA receivers.
- New agreement for enhanced support for 19 NOTA stations’ BINEX streams with a commercial client. Expanded scope of an existing contract to provide dedicated streams at 18 additional NOTA stations. Rehabilitation of previous BARGEN station, ALAM.
- Submitted a detailed justification to the NSF Program Manager outlining a possible fee-for-service paywall for NOTA RT-GNSS users.

Y2Q2:
- GI staff completed Wilderness First Aid, CPR, and tower climbing refresher courses in early February 2020 in San Clemente, CA. ~25 staff participated in the training and attended an equipment and procedures engineering meeting.
- Engineers completed a successful field operation in Panama including repairs and upgrades to 5 cGNSS stations, working in collaboration with the Smithsonian Tropical Research Institute. All stations were upgraded to full GNSS, and three stations are now streaming real-time data.
- Engineers completed a successful field visit to CN23, working with the Ministry of Natural Resources in Belize. Site communications were restored, along with preventative maintenance and upgrades to full GNSS.
• Dedicated streams at 20 NOTA stations were provided as for an existing commercial contract.

Y2Q3:
• GI-NOTA staff assisted with the preparation of materials for the Sensor Networks component of the NSF panel review of UNAVCO and IRIS.
• In response to restricted field operations as a result of the UNAVCO-wide COVID-19 policy, GI-NOTA staff took on numerous non-field efforts including NOTA station photo web services analysis, San Clemente warehouse organization, assisted in eliminating offensive language in UNAVCO materials, ShakeAlert Onboard PPP configuration and testing, ongoing efforts in necessary network DNS migration and field hardware strong password implementation.
• Due to a request by the landowner, GNSS station P549 was removed on June 26. This station was on the NOTA station decommissioning list.

Issues/challenges:
Y1Q4
• The Central American and Caribbean component of the NOTA network needed maintenance, repair, and upgrades following a period without dedicated O&M funding.
• Cellular modem replacements were required prior to 3G network service termination after 2019-12-31.

Y2Q1:
• Maintenance for Central American and Caribbean components of the NOTA network. Significant progress is being made with dedicated resources, although many stations are currently inoperable.
• Three offers were rejected to fill the engineering position in the Anchorage Office.

Y2Q2
• The COVID-19 pandemic has resulted in restrictions for travel, limited access to stations, and difficulties in coordination with landowners.
• The Anchorage office remains unstaffed, and COVID-19 restrictions in Alaska prohibit travel into and around the state resulting in canceled and delayed training and field operations.
• We anticipate further decreases in network uptime related to COVID-19 changes to operations.

Y2Q3:
• While some summer maintenance in Alaska is planned, the decision was made to cancel all helicopter operations for the remainder of 2020.

Resolved issues/challenges:
Y1Q4: Southwestern office was successfully relocated.
Y2Q1: Many 3G cellular modems have been successfully upgraded to RV50s. The deadline to upgrade the remaining modems has been relaxed.
Y2Q2: ~30 3G modem units remain to be upgraded.
Y2Q3: None to report.

NOTA GNSS Highlight Y1Q4: NOTA Captures Ridgecrest, CA Earthquake Sequence.

NOTA station P595 station was the closest to the epicenters of the Ridgecrest, CA earthquake sequence. Thanks to NOTA equipment/telemetry design and modernization, no NOTA station went offline during shaking; real time data continued to stream, enabling rapid magnitude estimates.

NOTA GNSS Highlight Y2Q1: Radio Network Upgrade

NOTA station RCA2 serves as a repeater for the 7-station Channel Islands radio network. A new 20’ rohn tower replaces the post previously installed in 1998 for the SCIGN project; modern GNSS + radios installed at related sites.

NOTA GNSS Highlight Y2Q2: Wilderness first aid and CPR training in San Clemente, CA.

Participants of Wilderness First Aid, CPR and tower climbing refresher training practice their skills at the San Clemente warehouse.
Geodetic Infrastructure

Borehole Geophysics

Borehole Geophysics Network Operations (U1.2.2)

GI supports the O&M of borehole strainmeters and seismometers, ancillary sensors (tiltmeters, pore pressure sensors, met packs) and support equipment as part of NOTA as well as smaller networks around the world including GeoGONAF (Turkey), CALIPSO (Montserrat), DOE (Oklahoma), and TABOO-STAR (Italy).

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Strain-meter Count</th>
<th>Strain Network Uptime</th>
<th>Seismo-meter Count</th>
<th>Seismic Network Uptime</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>87</td>
<td>91%</td>
<td>83</td>
<td>97%</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>87</td>
<td>94%</td>
<td>83</td>
<td>95%</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>87</td>
<td>91%</td>
<td>83</td>
<td>92%</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>87</td>
<td>91%</td>
<td>83</td>
<td>89%</td>
</tr>
</tbody>
</table>

Uptime: % of stations that delivered data within 1 day of collection.

Borehole Network Maintenance

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Engineer Days in Field</th>
<th>Site Visits</th>
<th>Maintenance Issues Resolved</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>60</td>
<td>31</td>
<td>58</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>18</td>
<td>18</td>
<td>30</td>
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<tr>
<td>2020 Jan-Mar</td>
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</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>14</td>
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</tr>
</tbody>
</table>

Notable activities:

Y1Q4:
- Tested firmware from GTSM and code to transfer files to Marmot and to convert bottle to miniseed.
- Made progress on new “real-time dynamic strain” data product.
- Deployed GTSM firmware with reduced calibration frequency at B010.
- Completed a visit to Mojave stations after M7.1 event in Ridgecrest, CA.
- Maintenance visit to GONAF stations in Turkey.
- Maintenance visit to Montserrat CALIPSO stations.
- BSM staff contributed to SRL Data Mine issue submission for Ridgecrest events.
- Identified new Yellowstone lake gauge location, and met with NPS staff.
- Transferred borehole logging equipment from Kandilli to AFAD for transport to Italy.
- PM Mencin filmed for National Geographic TV documentary on Yellowstone.

Y2Q1:
- Ongoing testing of new firmware from GTSM, code to transfer files to Marmot data loggers.
- Determined that 18 deployed GTSM loggers have incorrect processor clock speed settings, which will affect the deployment of real-time firmware. Correcting this issue requires a site visit. Four of these updates have been completed so far.
- Developed a list of 27 stations with 256MB of on-board storage on the GTSM logger, providing only 14 days of 20 Hz storage.
● Completed comprehensive documentation of Montserrat equipment and configuration.
● Implemented a daily voltage check email to warn BSM field staff of power issues at stations.
● Worked with AFAD (in Turkey) on power system design to move SIV1 to AC power.

Y2Q2:
● Real-time strain data development work continued during Y2Q2. Met with BRTT to discuss Antelope implementation of strain data transfer. Improved GTSM-Marmot code to run as part of Antelope.
● Developing automated event response plots including dynamic strain/magnitude, seismic, and tilt data. BSM Ops team supporting ECE efforts.
● Configured a cloud-based Antelope server in AWS to begin testing dataflow from sites to the cloud.
● BSM Team attended week-long WFA/CPR/Tower training and GI Ops meeting in San Clemente, CA.
● Tested/repaired/RMA’d returned GTSM equipment (5 PB, 9 LG, 8 OS).
● Continue to investigate Seiscomp3 as a possible Antelope alternative.

Y2Q3:
● During COVID 19 travel restrictions, field staff continued working on annual professional development goals, including learning Python coding for data manipulation and QC analysis.
● Continued real-time strain data development.
● Submitted a USGS NEHRP proposal ($100K, 2 years) to support real-time strain development.
● Completed automation of event response plots (via Jupyter Notebook) for dynamic strain magnitude estimates, seismic section, and tilt.
● Updated strainmeter quality control (QC) metrics, in coordination with GNSS QC efforts.
● Upgraded field task tracking system to work in conjunction with UNAVCO state of health mapping software. To-do list items now appear on the Network State Of Health map. All of GI uses this system.
● Organized a collaborative task force examining commercial alternatives for the aging Digital Image Management System currently in use.

Issues/challenges:
Y1Q4:
● GERD station on Montserrat was decommissioned due to loss of permit.
● Lack of spare CIS “shoebox” parts for Montserrat strainmeters. We now have a single non-functional spare from GERD.

Y2Q1:
● The Cascadia BSM F150 was stolen from PDX airport parking. It was recovered by local police, with minor damage.
● Outdated Marmot hardware does not support Antelope development using python or other modern programming languages. Investigating Seiscomp3 as a possible alternative to Antelope software platform.

Y2Q2:
● COVID-19 travel restrictions limited NOTA BSM fieldwork operations. Network uptime will be impacted, as will travel spending.
● Italy strainmeter installations, planned for Summer 2020, are delayed due to COVID-19.
● Limited roll-out of new GTSM firmware to support real-time dataflow has identified several problems, which need to be resolved prior to deployment.

Y2Q3:
● Continued outages with Verizon RV50s cellular modems.

Resolved issues/challenges:
● Y1Q4: Successfully initiated shipment of borehole logging gear from Turkey to Italy for pending TABOO-STAR installations.
● Y2Q1: Continued shipment logistics of borehole logging gear from Turkey to Italy for upcoming TABOO-STAR installations.
● Y2Q2 & Y2Q3: None to report.
NSF-EAR PI Support - GNSS (U1.3.1)

EAR Principal Investigator (PI) project support includes comprehensive technical support services to GAGE projects. These services range from technical proposal planning and budgeting support, field engineering, permanent and short-term instrument deployments, data collection, technical training, and on-call support. Support includes NSF-EAR asset management, equipment loans, testing, repair, configuration, integration, and development of new equipment designs. Support also includes permanent station O&M in coordination with PIs and local collaborators, primarily via project-specific funding.

GNSS PI Proposals

<table>
<thead>
<tr>
<th>Time Period</th>
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<th>Non-NSF</th>
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<tr>
<td>2020 Apr-Jun</td>
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</tr>
</tbody>
</table>

NSF-Other: proposals to programs other than EAR or OPP. Non-NSF: proposals to non-NSF programs (NASA, etc.).

GNSS PI Projects

<table>
<thead>
<tr>
<th>Time Period</th>
<th>NSF-EAR</th>
<th>NSF-Other</th>
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</tr>
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<td>2</td>
</tr>
</tbody>
</table>

NSF-Other: proposals to programs other than EAR or OPP. Non-NSF: proposals to non-NSF programs (NASA, etc.).

Notable activities:

Y1Q4:
- Deployed 19 GNSS campaign kits in response to the M6.4/M7.1 Ridgecrest earthquake sequence. This was in support of two different requests from PIs Y. Ben-Zion (USC) and B. Brooks (USGS).
- Finalized testing of the RTX position correction service on receivers that will be used as campaign systems with instantaneous position measurements with 2 cm accuracy. Now actively deploying these receivers to support PI projects.
- Completed 4 of 5 cGNSS station installations in support of “RAPID Geodetic Field Response to the 2018 Magnitude 7 Anchorage Earthquake.” The 5th station will be installed in Y2Q1. (PI: J. Elliot, Purdue; EAR-1917396).

Y2Q1:
- Project: “Geodetic Observations in the Northern Costa Rica Subduction Zone.” (PI Timothy Dixon - University of South Florida. NSF-EAR: 1345100)
  - Upgrades, maintenance, and relocation of a station in the 19 cGNSS network.
  - Completed installation of 5th cGNSS station.

Y2Q2:
- The following highlights have full details.
  - Contributing to Sustainable Farming in Bangladesh with GNSS (PI: Mike Steckler, Lamont-Doherty Earth Observatory, Columbia University, World Bank Funding).
    - Installation of cGNSS stations.
    - Installation of cGNSS stations.
Y2Q3:
● Provided UAS and TLS operation training to new Polar Engineer, Dr. Erika Schreiber.
● Continued support for the NSF funded RAPID project: *Quantifying Post-Seismic Crustal Deformation in SW Puerto Rico* (Award Abstract #2022264 )
  ○ Prepared the equipment enclosures
  ○ Prepared the power systems
  ○ Ordered and shipped antenna monument supplies (SDBM).

Issues/challenges:
Y1Q4, Y1Q1, Y2Q2: None to report.
Y2Q3:
● John Galetzka resigned from UNAVCO to join the National Geodetic Survey at NOAA, leaving a vacancy in the EAR PI support team.
● COVID-19 travel restrictions impacted facility support of some PI projects.

Resolved issues/challenges:
● Y1Q4, Y1Q1, Y2Q2, Y2Q3: None to report.


PI Support - GNSS Highlight Y2Q2: Supporting multiple projects in Nicaragua. (PI: Peter LaFemina, Penn State. NSF EAR-1826508, NASA 16-ESI16-0030, NOTA GNSS Ops support through GAGE). Provided training, GPS campaign measurement, cGPS installations, and repairs to existing stations.

Jim Normandeau (UNAVCO) trains Elvis Leif Mendoza Rivera (INETER) on how to replace a choke ring antenna LNA at the cGPS station MANA, in Managua. Elvis will be repairing two additional cGPS stations that are part of NOTA. (Photo courtesy of Peter LaFemina)
Geodetic Infrastructure
PI Support - Imaging

NSF-EAR PI Support - Terrestrial Imaging (U1.3.2)

Terrestrial Imaging support includes comprehensive project technical support services to GAGE projects centered on acquiring, distributing, archiving, and applying high precision terrestrial imaging geodetic data (e.g., terrestrial laser scanning (TLS) and structure from motion (SFM) photogrammetry). These services range from proposal planning and budgeting, in-field engineering services and instrument deployments, data collection, technical training and on call support. In addition, PI Project support includes NSF-EAR/OPP asset management and equipment loans, validation, configuration, and integration. (NSF-OPP activities are reported in the OPP CSA section.)

### Terrestrial Imaging PI Proposals

<table>
<thead>
<tr>
<th>Time Period</th>
<th>NSF-EAR</th>
<th>NSF-Other</th>
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<tr>
<td>2020 Apr-Jun</td>
<td>0</td>
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</tbody>
</table>

**Notable activities:**

Y1Q4:
- Acquisition of new UAS platforms and payloads to expand GAGE capabilities to support PI projects. New systems include: DJI Matrice 100 with Zenmuse X5 16 megapixel camera; DJI Matrice 210 v2 with RTK and Zenmuse X5S 20.8 megapixel camera. Additional sensors include MicaSense RedEdge-MX (Blue, green, red, red edge, near-IR) and MicaSense Altum (blue, green, red, red edge, near-infrared LWIR: thermal infrared 8-14um).

Y2Q1:
- Convened sUAS SIG: “Emerging applications for UAS (uncrewed aerial systems),” at the 2019 Joint SAGE-GAGE Science Workshop.

Provided support for TLS projects:
- Y2Q1-Y2Q2: Snow water equivalent (SWE) cal/val for the NASA SnowEx project (PI McGrath).
- Y2Q1-Y2Q3: Avalanche mechanics and forecasting (PI Hammonds - see highlight below. not counted in Y2Q2 or Y2Q3 quarter metrics).
- Y2Q2: Vadose zone characterizing the role of snow for liquid water storage transmission (PI Webb).

### Terrestrial Imaging PI Projects

<table>
<thead>
<tr>
<th>Time Period</th>
<th>NSF-EAR</th>
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</tr>
<tr>
<td>2020 Apr-Jun</td>
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</tr>
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</table>

**Issues/challenges:**

Y1Q4, Y2Q2: None to report.

Y2Q1: Ongoing troubleshooting of WiFi connectivity on the Riegl VZ-6000 scanner - currently negotiating loaner from Riegl to allow UNAVCO instrument to be returned to Austria for service in Q2.

Y2Q3: COVID-19 restrictions on travel along with social distancing requirements limited fieldwork and resulted in the cancellation of projects this quarter.

Resolved issues/challenges:

Y1Q4, Y2Q1, Y2Q3: None to report.

A detailed list of supported NSF-EAR PI projects is provided in Appendix A.
• Y2Q2: Riegl expedited repairs to our VZ-6000 scanner. During the repair period a loaner instrument was provided so as not to disrupt PI project support.

PI Support - Imaging Highlight Y1Q4: UAS Structure from Motion (SfM) survey of Lake Agnes Rock Glacier, Colorado. PI: D. McGrath, Colorado State University.

Very high resolution digital surface model of Lake Agnes Rock Glacier from UAS SfM survey. Data were collected in a single survey flight using a DJI Phantom 4 Pro UAS.

PI Support - Imaging Highlight Y2Q2: “Extending the vadose zone characterizing the role of snow for liquid water storage transmission” (PI Ryan Webb, UNM, NSF-EAR 1824152).

The results of bulk liquid water content, $\theta_w$ estimates for a. near tree line and b. above tree line, AT on bi. 15 May, 12:50 p.m.; bii. 15 May, 2:45 p.m.; and biii. 16 May, 7:00 p.m. See science snapshot: Measuring Snow Properties with Laser Scanning and Radar (Figure courtesy R. Webb)

PI Support - Imaging Highlight Y2Q3: Terrestrial laser scanning at Niwot Ridge and Cameron Pass, CO (Pis: McGrath & Webb)

The TLS data from the surface are combined with concurrent GPR snow depth/density measurements to provide a way to calculate Snow/Water Equivalent (SWE). 2-3 scans at each site were completed during the quarter and will continue through the summer as the snow melts. At Cameron Pass, we also scanned the tops of the Diamond Peaks as a proof of concept to test long range imaging of snow with the VZ-6000 in support of the upcoming NASA SnowEx project that will be collecting aerial lidar and radar data this winter. (Photo/UNAVCO)
Geodetic Infrastructure

GITS

Geodetic Instrumentation Technical Support (GITS) (U1.5.1)

The GITS team analyzes and integrates GNSS-enabled receivers and antennas, power systems, data communications devices, monumentation, and other technologies used by GAGE and PIs. Testing includes the use of high-precision GNSS data processing and analysis packages in both post-processed and real-time modes. GITS staff work with GNSS manufacturers to evaluate new hardware and analyze, debug, and identify improvements to existing hardware and firmware. Staff maintains the UNAVCO Online Knowledge Base, the primary means of dissemination of project results, firmware and software versions, and instructional documentation. GITS undertakes projects of interest to specific stakeholders (e.g., Polar projects that require ultra-low-power, NASA networks with specific software interface requirements) and of general interest to the community (e.g., the performance of systems during earthquakes).

<table>
<thead>
<tr>
<th>Time Period</th>
<th>GITS Projects Worked On</th>
<th>GITS Projects Completed</th>
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<td>1</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>12</td>
<td>3</td>
</tr>
</tbody>
</table>

Notable activities:

- Analyzed failure and performance of Trimble RTX onboard PPP positioning systems during Ridgecrest earthquake sequence. Failure was related to an unannounced change Trimble had made to MSS frequency used to broadcast corrections, which was firmware dependent. Some differences in performance between onboard and server-based RTX were suspected to have been related to age-of-corrections that differ by delivery method between the two systems.

Y2Q1:
- Septentrio PolaRx5 firmware upgrade, v5.3.1, fixed bugs from v5.3.0, and introduced advanced power monitoring. A beta-phase preliminary implementation of event-triggered logging sessions was tested and fine-tuned by GITS and was released in November and validated for deployment. Final documentation and rollout to all UNAVCO receivers will take place in Y2Q2.
- A trial version of Septentrio’s onboard PPP positioning feature was installed on an in-house receiver to test and develop new configurations for updated NOTA data flow.
- F. Blume, chair of the Scientific Organizing Committee for the IGS 2020 Workshop, presented the preliminary workshop plan to the IGS Governing Board and Associate Members meeting held on December 8, 2019 prior to the AGU Fall 2019 meeting in San Francisco, California.

Y2Q2 activities:
- Septentrio PolaRx5 firmware upgrade, v5.3.2, made minor improvements to GNSS message contents and added a new Cloud storage option for data transfer which may be of limited utility to some members of the UNAVCO Community.
- Septentrio’s onboard PPP positioning feature was tested on an in-house receiver and a new configuration for NOTA receivers developed.
- Deployed Septentrio’s onboard PPP positioning at NOTA station CORV in Corvallis, Oregon.
- UNAVCO is collaborating with the National Geodetic Survey to validate its new robot antenna calibration facility in Virginia.

Y2Q3:
- Trimble NetR9 firmware version 5.45 was tested and approved for deployment.
- UNAVCO’s online Knowledge Base was edited to remove culturally inappropriate terminology that had been in longstanding usage in the technology industry.
Issues/challenges:

Y1Q4:
- Trimble has yet to reschedule a critical meeting to review several outstanding technical questions, such as new runpkr00 software, receiver performance issues, and new antenna specs.
- Septentrio PolaRx5 firmware 5.3.0 release introduced some bugs that will be resolved in upcoming beta releases to be tested by the GITS group, including lack of sftp functionality.

Y2Q1:
- IGS Boulder Workshop Scientific Organizing Committee planning activities will require significant GITS staff time.

Y2Q2: None to report.

Y2Q3:
- After over a decade of controversy and testing, the FCC approved Ligado’s use of MSS L-Band spectrum adjacent to GPS L1, over continuing opposition from the Secretary of Defense, the NTIA, and high-ranking Senators and Representatives of both parties. While it is unlikely that deployment will happen anytime soon, if ever, UNAVCO must be prepared to react should harmful interference in the field become a reality.
- Ongoing issues with Trimble remain unresolved.

Resolved issues/challenges:

Y1Q4, Y2Q1, Y2Q3: None to report.

Y2Q2:
- The IGS 2020 Workshop originally scheduled for August 8, 2020 has been postponed until March 2021, which will limit the demands on GITS staff related to this task for the near-term.

GITS Highlight Y1Q4: TRM59800.99 PCV calibrations

GPS L1 and L2 phase center variations for the upgraded TRM59800.99 choke ring antenna as determined by Geo++ and published in a recent release of igs14.atx.

GITS Highlight Y2Q1: Online Geoid Height Calculator

UNAVCO’s online geoid calculator was developed in 1998 by Dr. F. Blume. The calculator used the NGA’s EGM96 geoid model, which has since been superseded by the higher-resolution EGM2008 model. The online calculator updated with the newer gravity model. Figure: High-resolution (2.5’) EGM2008 geoid heights relative to the WGS 84 ellipsoid.

GITS Highlight Y2Q2: Septentrio PolaRx5 Onboard PPP Positioning Tested and Deployed

Real-time onboard positions broadcast by in-house Septentrio PolaRx5 receiver with stationary antenna. Corrections are received from TerraStar SECORx system. Testing is ongoing to determine optimal systems settings as the service is being rolled out onto NOTA receivers in the PNW region. (Image/ UNAVCO)
**USGS ShakeAlert**

ShakeAlert is an earthquake early warning (EEW) system that detects significant earthquakes rapidly so that alerts can reach many people before strong ground shaking arrives. The USGS, along with partners including UNAVCO, is developing and testing the ShakeAlert System for the U.S. West Coast, including the integration of GNSS data.

**Y1Q4:**
- Award number: G17AC00313
- Award amount to UNAVCO: $1,190,495
- Project period: 8/15/17 to 8/14/19

**Y2Q1 - Y2Q3 Project information:**
- Award number: G19AC00287
- Award amount to UNAVCO: $1,519,712
- Project period: 8/15/19 to 8/14/21

**Y1Q4:**
The first ShakeAlert Cooperative Agreement between the USGS and UNAVCO expired on 8/14/19. All tasks in the original proposal and those included in the Y2 Supplemental Funding were completed on time and on budget. UNAVCO has been awarded a new ShakeAlert Cooperative Agreement that builds on the successful completion of the 2017-2019 award above.

**Y2Q1:**
UNAVCO was awarded a new ShakeAlert Cooperative Agreement that builds on the successful completion of the 2017-2019 award above.

**Y2Q2:**
The project continued to move forward despite some delays in fieldwork related to COVID-19 travel restrictions. Adam Woolace and Chad Pyatt, however, were able to complete reconnaissance for all five new sites to be installed during Y2 of the current Cooperative Agreement. Permitting has also commenced for all five new sites in Oregon.

**Y2Q3:**
The project continues to move forward despite some delays in fieldwork related to COVID-19 travel restrictions. All planned GNSS infrastructure and telemetry upgrades at NOTA sites in the Pacific Northwest have been completed for the first award year, as well as recons for 5 new sites in Oregon. Also, onboard Precise-Point-Positioning has been enabled on 101 receivers in this area (67 Septentrio RX5s and 34 Trimble NetR9s). 42 more are scheduled to be implemented before August 14, 2020. We are in the process of developing and testing dataflow, storage, and interpretation of these on-board solutions to be used in Earthquake Early Warning applications. An annual progress report was submitted to the USGS on June 30, 2020.
Geodetic Data Services

The GDS program manages a complex set of data, metadata and data flow systems, providing a wide range of geodetic/geophysical observations to scientific and educational communities.

GDS Advisory Committee (U2.1.1)

Y1Q4: The GDS AC advised GDS management throughout the quarter for the GAGE Data Services External Panel Review. The AC provided reviewed written responses submitted to NSF. The AC Chair, Dr. Julie Elliott, participated in the NSF review remotely.

Y2Q1: The IRIS/UNAVCO Joint Data Services (JDS) Committee Meeting was held October 12, 2019 in Portland, Oregon resulting in jointly agreed upon action items: establish a Cloud Solutions working group, develop a data service survey for a joint facility, establish regular meeting schedules for JDS meetings and to each organization’s DS committee meetings.

Y2Q2: No GDS advisory meeting was held this reporting period.

Y2Q3: The Geodetic Advisory Committee met in a virtual meeting May 6-7, 2020. Based on the review they compiled a set of recommendations that spanned community communication, data attribution, UNAVCO website, web services, data products and cooperation with IRIS.

GDS Program & Personnel Management (U2.1.2)

Notable activities:

Y1Q4

- GAGE/SAGE Data Services External Panel Review took place September 25-26, 2019 in Alexandria, VA and was attended by the GDS management team and GDS AC Chair. Written responses to review questions were submitted to NSF on August 1, 2020.

- GDS Director Meertens and PM Phillips attended the IUGG General Assembly and IGS Governing Board meeting in Montreal, Canada, on July 11-16, 2019.

- GDS staff made significant contributions to the Ridgecrest, CA earthquake response.

- Director Meertens and PM Phillips attended the NSF EarthCube Council of Data Facilities Shared Infrastructure Workshop in Denver on July 24-25, 2019.

- Two new Software Engineers were hired: Rachel Terry and Taylor Washington.
Y2Q1:  
- GDS members participated in the 2019 Joint Science Workshop of SAGE and GAGE in Portland, Oregon and hosted several Special Interest Group workshops including: "Geodetic data and products sharing: enable the future with web services?"; "SAGE/GAGE Common Data Access Point (CDAP)"; and GAGE Analysis Center meeting. Refer to the full 2019 SAGE/GAGE Workshop Report.
- The GAGE/SAGE Data Services External Panel review outcomes were sent to GAGE/SAGE in December 2019.
- GDS Director Meertens, F. Blume, and D. Maggert participated in the IGS Governing Board meeting held on December 9, 2019 prior to the 2019 AGU Fall meeting in San Francisco, California.
- Coordination with GAGE governance and project teams at Fall AGU meeting in San Francisco, California, including the GAGE GNSS Data Analysis group and a Joint UNAVCO/IRIS GDS/DMC Coordination Meeting.

Y2Q2:  
- Biweekly meetings with IRIS Data Management Center staff and GDS project management team to discuss common data access developments.
- Collected 7 custom high-rate GPS data sets, six as part of earthquake event response projects and the seventh in support of a surveying project across the Imperial and Tulecheck Faults in northern Baja Mexico. The six data event responses included:
  - January 7, 2020 M 6.4 Earthquake 8 km S of Indios, Puerto Rico
  - January 23, 2020 M 6.2 Earthquake 22 km E of Tanaga Volcano, Alaska
  - January 28, 2020 M 7.7 Earthquake 125 km NNW of Lucea, Jamaica
  - March 7, 2020 M 5.5 Earthquake 71km SE of Estacion Coahuila, B.C., Mexico
  - March 18, 2020 M 5.7 Earthquake 6 km NNE of Magna, Utah
  - March 31, 2020 M 6.5 Earthquake 72 km W of Challis, Idaho
- Initiated Event Response project to automatically generate maps, station lists and data sets using all GAGE data products for the community to use and to generate the event response highlight webpage.
- COVID-19 responses have impacted hiring personnel.

Y2Q3:  
- Multiple weekly meetings are taking place with IRIS Data Management Center staff and GDS project management team to create the project documentation for the combined Common Core Platform.
- Collected three custom high-rate GPS data sets, two as part of earthquake event response projects and the third in support of an ionospheric perturbation analysis project. The two data event responses included:
  - June 23, 2020 M 7.4 Earthquake 9 km SE of Santa Maria Xadani, Mexico (us6000ah9t).
  - June 25, 2020 M 5.8 - 18km SSE of Lone Pine, CA (ci39493944).
- The Event Response project to automatically generate maps, station lists and data sets using all GAGE data products has progressed into the JupyterHub phase for internal implementation.
- COVID-19 responses have impacted hiring personnel.

### GDS Program Personnel Headcount

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</table>

Budgeted and Actual Headcounts include EAR, OPP and NASA CSAs and other awards. Headcount includes individuals working non-GAGE projects, indirect costs, and individuals that cross-report.
**Geodetic Data Services**

**GNSS**

### GNSS Data (U2.2)

GDS supports the acquisition, network operations, archiving, curation, and distribution of the following GNSS data products.

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<thead>
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<th>Description</th>
<th>Format</th>
<th>Frequency</th>
<th>Creator</th>
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<tbody>
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<td>Standard rate data (15-sec)</td>
<td>Raw, BINEX</td>
<td>Hourly, Daily</td>
<td>UNAVCO</td>
</tr>
<tr>
<td></td>
<td>High rate data (1-, 2-, 5-sps)</td>
<td>Raw, BINEX</td>
<td>Hourly, Daily</td>
<td>UNAVCO</td>
</tr>
<tr>
<td></td>
<td>Real-time, high rate data stream</td>
<td>BINEX, RTCM</td>
<td>Real-time</td>
<td>UNAVCO</td>
</tr>
<tr>
<td></td>
<td>Community continuous data</td>
<td>Raw, RINEX</td>
<td>Hourly, Daily</td>
<td>Community</td>
</tr>
<tr>
<td></td>
<td>Survey-mode (campaign) data</td>
<td>Raw, RINEX</td>
<td>Varies</td>
<td>Community</td>
</tr>
<tr>
<td></td>
<td>Metadata</td>
<td>Data-base</td>
<td>Varies</td>
<td>UNAVCO</td>
</tr>
<tr>
<td>1</td>
<td>Standard rate data (15-sec)</td>
<td>RINEX</td>
<td>Daily, varies</td>
<td>UNAVCO</td>
</tr>
<tr>
<td></td>
<td>High rate data (1-, 2-, 5-sps)</td>
<td>RINEX</td>
<td>Varies</td>
<td>UNAVCO</td>
</tr>
<tr>
<td></td>
<td>Community continuous data</td>
<td>RINEX</td>
<td>Daily, varies</td>
<td>UNAVCO</td>
</tr>
<tr>
<td></td>
<td>Survey-mode (campaign) data</td>
<td>RINEX</td>
<td>Daily, varies</td>
<td>UNAVCO</td>
</tr>
<tr>
<td>2</td>
<td>Position solutions (unconstrained)</td>
<td>SINEX</td>
<td>Daily</td>
<td>CWU</td>
</tr>
<tr>
<td></td>
<td>Position solutions (constrained)</td>
<td>SINEX</td>
<td>Daily</td>
<td>MIT</td>
</tr>
<tr>
<td></td>
<td>Time series</td>
<td>ASCII, CSV</td>
<td>Daily</td>
<td>MIT</td>
</tr>
<tr>
<td></td>
<td>Velocity solutions (constrained)</td>
<td>ASCII</td>
<td>Monthly</td>
<td>MIT</td>
</tr>
<tr>
<td></td>
<td>Position offsets (e.g. coseismic)</td>
<td>ASCII</td>
<td>Varies</td>
<td>MIT</td>
</tr>
<tr>
<td></td>
<td>Tropospheric parameter estimates</td>
<td>ASCII</td>
<td>Daily</td>
<td>CWU</td>
</tr>
<tr>
<td></td>
<td>Position solution QA parameters</td>
<td>ASCII</td>
<td>Daily, varies</td>
<td>UNR</td>
</tr>
</tbody>
</table>

Subaward activities by CWU and MIT related to the generation of level 2 GNSS data products are reported in Appendices C and D, respectively.

### Network Data Operations (U2.2.1)

Network data operations include data collection software, web interfaces for entry of metadata and tracking of maintenance activities/equipment at field sites, reporting tools for site monitoring, and web services to retrieve data products.

Network data operations are supported by dedicated metadata management (MDM) and state-of-health (SOH) software systems developed at UNAVCO.

Notable activities:

**Y1Q4:**
- MDM development: Gathered requirements for enhancements to support NASA GGN stations. Demonstrated updated user interface and database to support troubleshooting event response and reporting to shareholders.
- New production release of GNSS and BSM data flow tools. Completed development and automated testing for rsync enhancement of real time streams against receiver hourly files.
- Completed migration of manufacturer table into POD database. All forms used by the PBO equipment database have been updated to reference POD.
- Deployed new release of metrics under Python 3.0. Includes changes to Python utilities used throughout the Python software developed by UNAVCO’s and enables migration to centralized logging.
- IGS website upgraded with new map showing stations. Also assisting with transition to AWS.
- PM Ertz attended NSF Large Facilities Cyberinfrastructure workshop in Alexandria, VA, Sept 16-17.

**Y2Q1:**
- MDM:
  - Support Bulk Maintenance Report creation for Receiver/Modem firmware/configuration updates.
  - Modified software to support equipment sharing between stations.
- Database:
  - Moved project data into POD from SQL Server.
  - Added station-project history table with start/end dates to projects to track project history for each station in POD.
  - Reprocessed tilt data to correct previous issues with incorrectly entered lat/long values.
- Dataflow:
  - Completed update to use real time flow and...
Septentrio rsync to create/capture high rate hourly data without downloads.
- Upgraded LDM to the latest release to support larger file sizes.

- IGS Site Support:
  - Completed website move to AWS.
  - Implemented online station map interface.
  - Developing new station pages for IGS site.

- Metrics:
  - Implemented NSF NOTA Network uptime metric as reported in the GNSS NOTA Operation & Modernization table, under section GNSS Network Operations (U1.2.1) of this report.

Y2Q2:
- MDM:
  - Support monitoring of Trimble Alloy receivers.
  - Maintenance Release: Fixed issue with SIM card updates being saved when maintenance report transaction failed. Also support emails to accounting when SIM cards are retired.
  - Support project history for stations.
  - Completed troubleshooting of interface for NASA stations.

- Database:
  - Completed functions to capture project history and Sim card history.

- Dataflow:
  - Completed development of rsync process to skip hourly downloads of real-time stations and integrated into GNSS dataflow.
  - Initiated the migration of borehole dataflow to Python 3.

- Database Consolidation:
  - Moved all project information with begin/end dates into POD from SQL server.

- GeoSciCloud:
  - Completed web services comparison testing at TACC. Working with analysis centers to complete their testing.

Y2Q3:
- MDM:
  - Deployed a release to fix issues when ESN or SIM Cards were swapped/removed/added during a cancelled maintenance report.
  - Implemented and deployed changes to capture highest sample rate allowable during automated event response requests. Maintenance report validates sample rate allowed after modem swaps.

- State of Health
  - Rewrote and deployed Python 3 version of Meteorological State of Health reports.

- Deployed enhanced Network Monitoring map.
- Metrics: Fixed issue with collection of TLS metrics when archive moved.
- Dataflow: Deployed rsync dataflow process for real time stations. Fixed issues with zombie processes.
- Data Downloader: Tested Invenio Open Source Framework allowing external users to archive their data.

Issues/challenges:
- Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.

Resolved issues/challenges:
- Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.

GNSS Data Highlight Y2Q3: Enhanced Network Monitoring map

Map provides quick view of station types and status. Table includes new user-expandable data columns to support field engineers for site visit planning. Expanded filtering provides more extensive query capabilities. (Image/ UNAVCO)
Data Products and Archives (U2.2.2)

Activities include the archiving, curation, quality assessment, and distribution of GNSS data products. Development and maintenance of software tools, databases, web services, and other resources that allow users to explore, visualize, and directly access data products are also supported.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Campaigns</th>
<th>Permanent Stations</th>
<th>All Stations with Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>5</td>
<td>2,605</td>
<td>13,764</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>11</td>
<td>2,609</td>
<td>13,792</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>0</td>
<td>2,628</td>
<td>13,815</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>5</td>
<td>2605</td>
<td>13,914</td>
</tr>
</tbody>
</table>

All Stations with Data: total number of GNSS stations with data maintained in archive, including all campaigns and all permanent networks (active and retired).

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Archived (GB)</th>
<th>Delivered (GB)</th>
<th>Users (Unique IPs)</th>
<th>Users (2nd Level Domains)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>10,050</td>
<td>18,292</td>
<td>9,815</td>
<td>3,520</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>7,928</td>
<td>13,837</td>
<td>17,224</td>
<td>4,253</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>8,325</td>
<td>29,689</td>
<td>13,187</td>
<td>3,992</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>9,690</td>
<td>14,522</td>
<td>8,922</td>
<td>3,185</td>
</tr>
<tr>
<td>All Time</td>
<td>206,623</td>
<td>433,780</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Users are unique IP addresses and 2nd level domains that downloaded data from UNAVCO FTP site.
Unique IP addresses are a proxy for individual users.
2nd level domains are a proxy for institutions.

Appendices A and B list GNSS networks archived for EAR and OPP projects, respectively. Appendices C and D report subaward activities to generate level 2 GNSS data products by CWU and MIT, respectively.

Notable activities:
Y1Q4:
- Significant time and effort was dedicated to the GAGE SAGE Data Services External Panel Review (written responses and presentations).
- Hosted collaborators Rui Fernandez and Paul Crocker who visited UNAVCO from the Space and Earth Geodetic Analysis Laboratory (SEGAL) of Portugal on Sep 16-17, 2019 as part of continued SAVI Coopeus collaboration.
- Completed development of a tool to analyze time series and generate uptime metric for any station.
- New GeoServer GNSS database views.

- 1 physical and 2 virtual Solaris machines retired and replaced with new VMs running CentOS 7 OS.
- 261 GNSS dataset DOIs were minted.
- Collected 8 custom GNSS PI datasets including 3 earthquake response (M6.4 Searles, CA; M7.1 Ridgecrest, CA; M6.0 Puerto Rico), 3 NCALM LiDAR projects, 1 DGGS/FEMA, and 1 USACE.

Y2Q1:
- Released ITRF2014 (NAM14/IGS14) products. NAM08/IGS08 products will continue to be generated in parallel until December 12, 2019. Notice to unav-all sent during the Joint Science Workshop of SAGE and GAGE in Portland, Oregon.
- Accompanying this reference frame change is the release of fully re-processed products in NAM14/IGS14 for all analyzed stations back through 1996. The simultaneous change in operational processing and release of reprocessed products was planned to ensure that no artificial offsets were introduced into any time series due to the reference frame change.
- Posted first PI contributed velocity file (Rui and Stamps, 2019) to data-out FTP site.
- PM Phillips led 3 SIG’s at the 2019 Joint Science Workshop of SAGE and GAGE related to data products, data standards and access, and a conceptualized GAGE-SAGE Common Data Access Point.
- PM Phillips, DE Puskas and SE Enloe presented at the 2019 Joint Science Workshop of SAGE and GAGE.
- PM Phillips and DE Puskas presented at the 2019 Fall AGU Meeting.
- Developed and implemented a script for NAGIOS to replace GSAC with a webapp.
- Collected 2 custom GNSS PI datasets including 2 earthquake responses, 1 NCALM LiDAR project.
- There were 358 GNSS Data DOI’s minted this quarter by UNAVCO.

Y2Q2:
- Released ITRF2014 (NAM14/IGS14) products. NAM08/IGS08 products continue to be generated in parallel.
- GNSS New Data Products Special Interest Group Notice proposed for the GAGE-SAGE 2020 Meeting.
- Initiated Event Response project to automatically generate maps, station lists and data sets using all GAGE GDS products for the community to use and to generate the event response highlight webpage.
● Data quality QC group established to define metrics for high-rate data sets.
● There were 51 GNSS Data DOI’s minted this quarter by UNAVCO.

**Y2Q3:**
● GNSS New Data Products Special Interest Group Notice at the GAGE-SAGE 2020 Meeting has been cancelled because of COVID-19.
● Collected three custom high-rate data sets, two as part of earthquake event response projects and the third in support of an ionospheric scintillation study with 5-sps and 20-sps data.
● Developed draft-version JupyterHub-based Event Response highlight webpage to automatically generate maps, station lists and data sets using all GAGE GDS products for the community to use and to generate the event response. The project has progressed to an internal-testing stage.
● Data quality QC group is examining how to quantify data quality in the frequency domain to parallel QC methodologies used by IRIS. This work has been extended to include strain analysis.
● There were 62 GNSS Data DOI’s minted this quarter by UNAVCO.

**Issues/challenges:**
Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.

**Resolved issues/challenges:**
Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.
Real-Time GNSS Data (U2.3.1)

RT-GNSS data streams support a broad spectrum of scientific, educational, and commercial user communities. GI staff maintain the sensor network and telemetry systems. GDS staff support RT-GNSS raw data and position products, processing, formats, standards, analysis and distribution. RT-GNSS data directly support various multi-agency activities including (but not limited to): Earthquake Early Warning, Tsunami Early Detection and Warning, and volcanic hazard assessment. GDS support also includes the development, implementation and distribution of automated and interactive tools, web services and associated web support to generate, quality-check, curate, and analyze RT-GNSS data.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Station Count</th>
<th>Completeness</th>
<th>Median Latency (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>955</td>
<td>85%</td>
<td>154</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>955</td>
<td>86%</td>
<td>152</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>968</td>
<td>86%</td>
<td>159</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>971</td>
<td>85%</td>
<td>210</td>
</tr>
</tbody>
</table>

### RT-GNSS Network Performance

Notable activities:

Y1Q4:

- 89 new RT-GNSS users were registered in Y1Q4 (12 Government, 19 Academic, 58 Commercial).
- The Trimble casters have been removed entirely from the real-time GNSS system. All data are being distributed with BKG open-source casters.
- Jianghui Geng of Wuhan University, China, visited UNAVCO in July 2019 to install GSEISRT real-time Precise Point Positioning software in the Amazon cloud. UNAVCO is now feeding the 54 original ShakeAlert sites into this software and is working with Jianghui to develop a cloud-based RT-PPP processing system.
- 169 NOTA RT-GNSS sites broadcast PPP solutions during the M7.1 Ridgecrest earthquake sequence. This solution indicated the event was a M7.0±0.3 within ~13 seconds of the origin time.

RT-GNSS data users are unique authenticated users. This table reports the active number of users who accessed data during the time period specified; this is a subset of the 1601 total registered users.
Y2Q1:
- 88 new RT-GNSS users were registered in Y2Q1 (5 Government, 17 Academic, 66 Commercial).
- Set up one new station, KUGE, in Nepal for real-time streaming and is maintained by the Kathmandu University Geomatics Engineering Department.
- Assisted the Instituto Geofísico, Escuela Politécnica Nacional, Ecuador in setting up real-time GNSS data processing for their GNSS+Seismic network.
- Discussion of NOTA GNSS Real-time GNSS operation held at Special Topic Session at SAG/GAGE Workshop, Oregon, October 2019.
- Two presentations given at Fall AGU 2019, San Francisco, CA on the NOTA Real-time data collection during the 2019 Ridgecrest Sequence.

Issues/challenges:
Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.

Resolved issues/challenges:
Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.

Y2Q2:
- 85 new RT-GNSS users were registered this quarter, Y2Q2 (6 Government, 24 Academic, 55 Commercial).
- Added 13 more stations to the real-time network.
- Real-time BINEX to RTCM3 translation code completed. Work continues on moving the entire system to the cloud.
- Presentation provided to the California Office of Emergency Services on March 12, 2020 (via Zoom) on the benefit of GNSS to Earthquake Early Warning by Walls, Hodgkinson and Mattioli.
- Enabled on board positioning at 4 GNSS stations in the field and in Boulder HQ for testing.
- Building tool sets, code and Jupyter notebooks do evaluate stream quality.

Y2Q3:
- 79 new RT-GNSS users registered in this quarter, Y2Q3 (10 Government, 11 Academic, 58 Commercial).
- Real-time BINEX to RTCM3 translation code completed. Work continued on moving the entire system to the cloud.
- Real-time translation from BINEX to RTCM3.1 is now performed by UNAVCO written software. The Trimble commercial software has been phased out.
- Real-time generated RTCM3.3 undergoing beta-testing.
- Enabled on board positioning at 63 GNSS stations in the field, to stream on-board solutions to Boulder in GSOF or NMEA format.
- Building tool sets, code, and Jupyter notebooks to evaluate data stream quality.
GDS supports the acquisition, curation and distribution of the following Synthetic Aperture Radar (SAR) data products.

### SAR Data Products

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Format</th>
<th>Frequency</th>
<th>Creator</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Raw sensor data and metadata</td>
<td>Varies</td>
<td>Varies</td>
<td>Space Agency</td>
</tr>
<tr>
<td>1</td>
<td>Single look complex (SLC) data</td>
<td>Varies</td>
<td>Varies</td>
<td>Space Agency</td>
</tr>
<tr>
<td>2</td>
<td>Interferograms</td>
<td>HDF-EOS5</td>
<td>Varies</td>
<td>Community</td>
</tr>
<tr>
<td>3</td>
<td>Time series and velocities</td>
<td>HDF-EOS5</td>
<td>Varies</td>
<td>Community</td>
</tr>
</tbody>
</table>

With the exception of freely available Sentinel-1 data, most SAR data providers (Japanese Aerospace Exploration Agency (JAXA), Deutsches Zentrum für Luft-und Raumfahrt (DLR, German Aerospace Center), Italian Space Agency (ASI), Canadian Space Agency (CSA)) do not make data or tasking openly accessible. Thus GDS activities to support the WinSAR community include satellite tasking, ordering data and metadata management, and facilitating data discovery and access.

### SAR Data (U2.4.1)

Activities include the development and implementation of data archives and web services, community support for satellite tasking, data ordering, and data download, and WinSAR community support tasks such as new member administration, ISCE software licensing, and Executive Committee support.

### SAR Data

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Archived (GB)</th>
<th>Delivered (GB)</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>300</td>
<td>1,698</td>
<td>17</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>13,380</td>
<td>1,733</td>
<td>14</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>10,749</td>
<td>4,320</td>
<td>14</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>2093</td>
<td>11812</td>
<td>20</td>
</tr>
<tr>
<td>All Time</td>
<td>180,356</td>
<td>125,704</td>
<td>20</td>
</tr>
</tbody>
</table>

SAR data users are unique authenticated users.

### WinSAR Community

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Full</th>
<th>Adjunct I</th>
<th>Adjunct II</th>
<th>Registered Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>113</td>
<td>18</td>
<td>172</td>
<td>1684</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>113</td>
<td>18</td>
<td>172</td>
<td>1712</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>114</td>
<td>18</td>
<td>181</td>
<td>2010</td>
</tr>
</tbody>
</table>

This table reports the number of registered WinSAR Institutions and users. Institutional types are as follows:

- **Full**: U.S. institutions. Full Members participate in WinSAR governance by electing members of the WinSAR Executive Committee, have access to the ISCE software and all data in the WinSAR ESA and EarthScope data collections, and may submit requests for tasking and data to be added to WinSAR collections at the UNAVCO SAR Archive.
- **Adjunct I**: Institutions in Canada and Mexico. Adjunct I Members also have access to the ISCE software and all data in the WinSAR ESA and EarthScope data collections, but cannot request tasking or ordering of additional SAR data.
- **Adjunct II**: All other institutions. Adjunct II Members only have access to the ISCE software and the ESA data in the WinSAR and EarthScope data collections.

Notable activities:

**Y1Q4**:
- Deployed JupyterHub on Jetstream/XSEDE for two SAR short courses using ISCE software and other open source tools (GDAL, numpy, scipy).
- Presented SAR data search and access courses: InSAR Processing and Theory with GMTSAR short course held in La Jolla, CA, in July and the 2019 InSAR Theory and Processing held in Boulder, CO.

**Y2Q1**:
- Organized annual WinSAR business meeting at the 2019 AGU fall meeting.

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Y2Q2:
- XSEDE allocation request for resources at Indiana University (IU) (Wrangler and Jetstream) granted.

Y2Q3:
- Migrated full SAR archive backup to cloud object storage on Wasabi following decommissioning of XSEDE Wrangler storage system at TACC.
- Conducted Membership management (10 new institutional member applications this quarter) in response to virtual short courses to be taught in next quarter.

Issues/challenges:
Y1Q4: None to report.
Y2Q1: SAR archive systems and data currently rely on XSEDE allocation. Current allocation needs to be renewed in January 2020.

Y2Q2:
- SAR archive systems and data currently rely on XSEDE allocation. Although our allocation request was granted for 2020, the Wrangler storage system at IU will be decommissioned at the end of 2020, and it appears a replacement will not be available. Thus, by the end of GAGE Y3Q1 we will need to migrate the full SAR archive to another system.

Y2Q3:
- SAR archive systems and data currently rely on XSEDE allocation. Although our allocation request was granted for 2020, the Wrangler storage system at IU will be decommissioned at the end of 2020, and it appears a replacement will not be available. Thus, by the end of GAGE Y3Q1 we will need to migrate the full SAR archive to another system.

Resolved issues/challenges:
Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.

SAR Highlight Y1Q4: InSAR Processing and Theory with GMTSAR Short Course

Participants from the InSAR Processing and Theory with GMTSAR short course held in La Jolla, CA, in July 2019. (Photo/David Sandwell, UCSD)

SAR Highlight Y2Q3: WinSAR, COMET, MDIS statement on “Terminology in InSAR”

An Open Statement on Terminology in InSAR

Since the early days of InSAR, the problematic terms “master” and “slave” have been commonly used to refer to the two images used to form an interferogram. This terminology is also used in other fields, including some optical image processing literature. We, the undersigned, commit to using alternative terminology in our publications, presentations, software, and teaching material going forwards. In our roles as editors and reviewers we will also insist that these terms are no longer used.

Full comment text available at: https://comet.nerc.ac.uk/about-comet/insar-terminology/
Geodetic Data Services

Geodetic Imaging

GDS supports the acquisition, curation and distribution of high precision terrestrial imaging geodetic data (e.g., terrestrial laser scanning (TLS) and structure from motion (SfM) photogrammetry) including the following data products.

### Geodetic Imaging Data Products

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Format</th>
<th>Frequency</th>
<th>Creator</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Scanner data, metadata, imagery</td>
<td>Raw</td>
<td>Varies</td>
<td>UNAVCO</td>
</tr>
<tr>
<td>1</td>
<td>Point clouds (unclassified, single scan pos)</td>
<td>ASCII, LAS</td>
<td>Varies</td>
<td>UNAVCO</td>
</tr>
<tr>
<td>2</td>
<td>Point clouds (classified, georeferenced)</td>
<td>ASCII, LAS</td>
<td>Varies</td>
<td>UNAVCO/Community</td>
</tr>
<tr>
<td>3</td>
<td>Point clouds (classified, georeferenced)</td>
<td>LAS, varies</td>
<td>Varies</td>
<td>Community</td>
</tr>
<tr>
<td></td>
<td>Raster (e.g., DEMs)</td>
<td>Varies</td>
<td>Varies</td>
<td>Community</td>
</tr>
</tbody>
</table>

### Geodetic Imaging Data (U2.5.1)

GDS provides geodetic imaging data products and services including Terrestrial Laser Scanning (TLS). Activities include the development, implementation and maintenance of data archive infrastructure, web services, and associated web content to support TLS data users. GDS also provides software to PIs for advanced TLS data processing and analysis.

#### TLS Data

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Campaigns Archived</th>
<th>Archived (GB)</th>
<th>Delivered (GB)</th>
<th>Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>1</td>
<td>1</td>
<td>68</td>
<td>7</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>1</td>
<td>3</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>10</td>
<td>163</td>
<td>0.026</td>
<td>1</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>2</td>
<td>72</td>
<td>108</td>
<td>13</td>
</tr>
<tr>
<td>All Time</td>
<td>242</td>
<td>7,892</td>
<td>7,073</td>
<td></td>
</tr>
</tbody>
</table>

*TLS data users are unique authenticated users.*

Notable activities:

**Y1Q4:**
- Taught a pair of short courses at the 2019 Geological Society of America (GSA) meeting in Phoenix, AZ: [Introduction to Terrestrial Laser Scanning (TLS)] and [Introduction to Structure from Motion (SfM) Photogrammetry] courses were both well attended. Resources from both courses are available on the UNAVCO Knowledgebase.

**Y2Q1:**
- Completed integration of community software licenses onto single license server.

**Y2Q2:**
- Completed migration of the Imaging data archive system to a new VM environment and to newer UNAVCO SAN hardware for storage. This work resulted in outages to data access and lower than normal data utilization metrics. During the final weeks of Q2, a concerted effort was made to ingest a backlog of datasets into the archive.
- Addressed issues related to Trimble Business Center software license access.

**Y2Q3:** None to report.

Issues/challenges:

**Y1Q4, Y2Q2, Y2Q3:** None to report.

**Y2Q1:**
- Problems with the Imaging data archive system have necessitated a migration to a new VM environment and to newer UNAVCO SAN hardware for storage. This resulted in outages to data access and lower than normal data utilization metrics. Migration to new hardware is ongoing with expected completion early Y2Q2.

Resolved issues/challenges:

**Y1Q4, Y2Q1:** None to report.

**Y2Q2:** Completed migration of archive system to new VM and SAN.

**Y2Q3:** Completed migration of archive system to new VM and SAN.
Geodetic Imaging Highlight Y1Q4: GSA Short Course

Participants learn about Terrestrial Laser Scanning and Structure from Motion at the Geological Society of America meeting. (Image/UNAVCO)

Geodetic Imaging Highlight Y2Q1: Newly archived dataset: Characterizing the role of snow for liquid water storage and transmission (PI Ryan Webb, UNM, NSF-EAR: Hydrologic Sciences, https://doi.org/10.7283/cbjg-g696)

Terrestrial laser scanning point cloud data colored by camera RGB imagery from a site at Niwot Ridge, CO where the PI is integrating repeat TLS data with ground penetrating radar to characterize and constrain the physical mechanisms that control snowmelt delivery to streams in headwater basins. (Image/UNAVCO)

Geodetic Imaging Highlight Y2Q2: Newly archived dataset: Lake Agnes Rock Glacier SfM survey (PI Daniel McGrath, CSU, https://doi.org/10.7283/w1pe-hj04)

Structure from motion photogrammetric digital elevation model of the Lake Agnes Rock Glacier in Colorado. Imagery used to produce this dataset was collected by UNAVCO sUAS.

Geodetic Imaging Highlight Y2Q3: Newly archived dataset: Adélie Penguin colony survey (B-031) - Cape Crozier (PS01) https://doi.org/10.7283/wpxk-1202

Field engineer K. Williams prepares a UNAVCO sUAS for a survey of the Adélie Penguin colony, Antarctica. (Photo/A. Zaino, UNAVCO)
Geodetic Data Services

Borehole Geophysics

GDS supports the acquisition, network operations and curation of the following borehole geophysics data products.

Borehole Geophysics Data Products

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Format</th>
<th>Frequency</th>
<th>Creator (Archive)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Raw strain time series</td>
<td>Bottle,</td>
<td>Hourly,</td>
<td>UNAVCO (IRIS)</td>
</tr>
<tr>
<td></td>
<td>(20-sps, 1-sps, 10-min)</td>
<td>SEED</td>
<td>Daily</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Raw seismic data</td>
<td>SEED</td>
<td>Real-time</td>
<td>UNAVCO (IRIS)</td>
</tr>
<tr>
<td></td>
<td>(100-sps)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Environmental time series</td>
<td>Bottle,</td>
<td>Hourly,</td>
<td>UNAVCO (IRIS)</td>
</tr>
<tr>
<td></td>
<td>(1-sps, 30-min)</td>
<td>SEED</td>
<td>Daily</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Instrument SOH time series</td>
<td>Bottle,</td>
<td>Hourly,</td>
<td>UNAVCO (IRIS)</td>
</tr>
<tr>
<td></td>
<td>(30-min, 1-hr)</td>
<td>SEED</td>
<td>Daily</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Borehole geophysical logs, samples</td>
<td>Varies</td>
<td>Installation</td>
<td>UNAVCO (IRIS)</td>
</tr>
<tr>
<td></td>
<td>Metadata</td>
<td>SEED</td>
<td>Varies</td>
<td>UNAVCO (IRIS)</td>
</tr>
<tr>
<td>2</td>
<td>Corrected, scaled strain time series</td>
<td>XML,</td>
<td>Daily,</td>
<td>UNAVCO (IRIS)</td>
</tr>
<tr>
<td></td>
<td>(5-min, 1-sps)</td>
<td>ASCII</td>
<td>Varies</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Station notebooks</td>
<td>PDF</td>
<td>Varies</td>
<td>UNAVCO (IRIS)</td>
</tr>
</tbody>
</table>

Ancillary products include borehole pore pressure, tiltmeter, and meteorological data. The SAGE Facility operated by IRIS supports GAGE borehole data archiving and distribution.

Borehole Geophysics Data (U2.6.1)

Borehole network data operations include software support for data collection, web interfaces for entry of metadata and tracking of maintenance activities and equipment at field sites, reporting tools to improve site monitoring, and web services to retrieve data products.

Borehole Geophysics Data Return

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Strainmeters (%)</th>
<th>Seismometers (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>89%</td>
<td></td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>93%</td>
<td>95%</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>90%</td>
<td>92%</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>88%</td>
<td>91%</td>
</tr>
</tbody>
</table>

Data return: % of data delivered versus expected; delivery of all expected data equals 100% data return.

Borehole Geophysics Data - Strain

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Archived (GB)</th>
<th>Delivered (GB)</th>
<th>Users (Unique IPs)</th>
<th>Users (2nd Level Domains)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>103</td>
<td>262</td>
<td>716</td>
<td>93</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>174</td>
<td>739</td>
<td>1266</td>
<td>95</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>102</td>
<td>1426</td>
<td>654</td>
<td>41</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>100</td>
<td>625</td>
<td>734</td>
<td>71</td>
</tr>
<tr>
<td>All Time</td>
<td>4,899</td>
<td>13,753</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Users are unique IP addresses and 2nd level domains that downloaded data from UNAVCO FTP site.

Borehole Geophysics Data - Seismic

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Archived (GB)</th>
<th>Delivered (GB)</th>
<th>Users (Unique IPs)</th>
<th>Users (2nd Level Domains)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>226</td>
<td>1,071</td>
<td>381</td>
<td>169</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>229</td>
<td>12,785</td>
<td>2320</td>
<td>201</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>214</td>
<td>1,501</td>
<td>263</td>
<td>110</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>204</td>
<td>1,748</td>
<td>449</td>
<td>162</td>
</tr>
<tr>
<td>All Time</td>
<td>11,593</td>
<td>97,967</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Users are unique IP addresses and 2nd level domains that downloaded data from UNAVCO FTP site.

Notable Activities

Y1Q4:
- Three custom BSM datasets were collected in response to earthquakes:
  - 2019-07-04 M6.4 Searles Valley, California
  - 2019-07-06 M7.1 Ridgecrest, California
  - 2019-07-15 M7.3 Indonesia
- GDS and IRIS DMC staff jointly participated in collaborative monthly conference calls.
- The dynamic strains generated by the Ridgecrest earthquake sequence were used to examine Mw using earthquake magnitude scaling laws. While distant BSMs (>100km from epicenter) recorded strains similar to theoretical values those in the near-field underestimated it for both the M7.1 and M6.4. It is possible the scaling laws are biased due to lack of near field observations.

Y2Q1:
- Two custom BSM datasets were collected in response to earthquakes:
  - 2019-10-15 M4.7 - 17km SSE of Tres Pinos, California.
  - 2019-10-15 M 4.5 - 1km SSE of Pleasant Hill, California.
- GDS and IRIS DMC staff jointly participated in collaborative monthly conference calls.
• Work continues on established real-time data flow from the strainmeter data loggers.
• Presentations on the Ridgecrest strains were given by Andy Barbour (USGS) at the Joint Science Workshop of SAGE and GAGE in Portland, Oregon.
• Presentations given at AGU 2019 by Noha Farghal (USGS) and UNAVCO Staff on the dynamic strains recorded during the Ridgecrest sequence.

Y2Q2:
• Four custom BSM datasets were collected in response to earthquakes:
  ○ M 7.7 - 125km NNW of Lucea, Jamaica (May 05, 2019).
  ○ M 5.7 - 6km NNE of Magna, Utah (March 18, 2020).
  ○ M 7.5 - 219km SSE of Severo-Kuril’sk, Russia (March 25, 2020).
  ○ M 6.5 - 72km W of Challis, Idaho (March 31, 2020).
• GDS and IRIS DMC staff jointly participated in collaborative monthly conference calls.
• Work continues on established real-time data flow from the strainmeter data loggers.
• None to report.

Y2Q3:
• Two custom BSM datasets were collected in response to earthquakes:
  ○ M 5.8 - 18km SSE of Lone Pine, CA (June 24, 2020).
  ○ M 7.4 - 12 km SSW of Santa María Zapotitlán, Mexico (June 23, 2020).
• GDS and IRIS DMC staff jointly participated in collaborative monthly conference calls.
• Work continues on established real-time data flow from the strainmeter data loggers.

Issues/challenges:
• Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.

Resolved issues/challenges:
• Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.
Information Technology (IT) (U2.7.1)

Information Technology includes the operation and troubleshooting of computer systems and networks for the GAGE Facility. System administration includes provision and maintenance of project servers and data storage units, installing system software and maintaining connectivity. It also includes the support needed to administer, configure and maintain the network that is used for gathering data from sensors, providing online sensor monitoring and maintaining/implementing new security features so that events such as cyber-attacks are discovered. Web administration encompasses the technical support of the website including web server configuration, monitoring, statistics collection and implementation of dynamic content to produce a well-organized, polished and easy-to-navigate website.

<table>
<thead>
<tr>
<th>IT System Administration Issue Tracking</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Period</td>
<td>Issues Opened</td>
<td>Issued Closed</td>
</tr>
<tr>
<td>2019 Jul-Sep</td>
<td>154</td>
<td>139</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>23</td>
<td>87</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>114</td>
<td>68</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>81</td>
<td>122</td>
</tr>
</tbody>
</table>

Notable activities:
Y1Q4 activities:
- Deployed and provided training for 1Password password manager across UNAVCO.
- Installed 2 new Oracle disk trays (225+ TB).
- Installed 2 Dell 740xd units with GPUs.
- Created 37 new VPN circuits for NOTA stations.
- Initiated work with Indiana University to transition offsite data services from FRRI to IU.
Y2Q1:
- Completed purchase and installation of new backup system.
- Storing FTP archive at Indiana University in 30 day incrementals backups.
Y1Q4, Y2Q1, Y2Q3: None to report.

Issues/challenges:
Y1Q4:
- VPN issues with Palo Alto router for NOTA ops.
- Current tape backup unit does not provide sufficient storage capacity, needs to be replaced with equivalent capability.
Y2Q1:
- Down one resource and keeping up with workload.
- Qualified candidate pool for system administrator is small.

Resolved issues/challenges:
Y1Q4, Y2Q1, Y2Q3: None to report.
Y2Q2:
- Hired new IT employee to fill vacancy.
GeoSciFramework

Collaborative Research: “Scalable Real-Time Streaming Analytics and Machine Learning for Geoscience and Hazards Research.” Development of a real-time processing system capable of handling a large mix of sensor observations focused on automating the detection of natural hazard events using machine learning as the events are occurring.

- NSF-OAC-1835791
- $830,728; 01/01/2019 - 12/31/2022.

GeoSciCloud

EarthCube Building Blocks: Collaborative Proposal: “Deploying Multi-Facility Cyberinfrastructure in Commercial and Private Cloud-based Systems (GeoSciCloud).” UNAVCO and IRIS data centers and GAGE analysis centers are deploying data collections and processing services in different cloud environments to assess feasibility and impact.

- NSF-EAR-1639709
- $605,204; 09/15/2016 - 08/31/2020 (NCE).

SAVI COOPEUS

SAVI: “Building a framework between the EU and the USA to harmonize data products relevant to global research infrastructures in the environmental field.”

- Four U.S. observatories including UNAVCO and IRIS are working together with European Union counterparts to develop common data policies and standards relevant to global research infrastructures in the environment field.
- NSF-ICER-1321641
- $180,457; 08/31/2013 - 08/30/2020 (NCE).
- GDS Personnel: C. Meertens.
The Education and Community Engagement (ECE) portfolio includes: community engagement, education, outreach, and workforce development.

Work is summarized by GAGE WBS elements. The ECE portfolio benefits all aspects of the GAGE Facility. Information presented here summarizes support through EAR, OPP, and NASA CSAs.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>EWO Activities*</th>
<th>Higher Education &amp; Science*</th>
<th>K-12, General Public*</th>
<th>Other Professional*</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>26</td>
<td>758</td>
<td>26</td>
<td>320</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>23</td>
<td>831</td>
<td>60</td>
<td>152</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>12</td>
<td>387</td>
<td>255</td>
<td>38</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>13</td>
<td>2045</td>
<td>1523</td>
<td>71</td>
</tr>
<tr>
<td>Total</td>
<td>74</td>
<td>4021</td>
<td>1864</td>
<td>581</td>
</tr>
</tbody>
</table>

*short courses, workshops, internship programs, outreach events, community engagement activities, and similar events; target = 55/yr
+ Individuals reached through all activities; target=1500/yr

The GAGE Facility surpassed its targets for number of activities executed and number of individuals engaged.

Higher than normal engagement occurred in 2019 July-September with high enrollment in short courses, science communication workshops, and technical presentations. The Joint GAGE/SAGE Science Workshop in Portland in October 2019 reached a large number of individuals in Higher Education & Science. A virtual presentation about science communication was given to over 1500 individuals at the University of Colorado Conference on World Affairs in April 2020. The GAGE facility helped facilitate the transition to online learning and training in spring 2020 with the COVID-19 situation. We facilitated webinars and presentations and partnered with the National Association of Geoscience Teachers (NAGT) professional society to provide guidance on converting geoscience courses to an online format with a particular focus on incorporating data in the classroom (GETSI project).

ECE Advisory Committee (U3.1.1)

The ECE Advisory committee met twice during this 12 month reporting period: an in-person meeting in August 2019 and a video conference call in April 2020. Email communication and discussion occurred throughout the year.

ECE Program & Personnel Management (U3.1.2)

The ECE program staffing includes the director, an administrative assistant, and two full-time and three part-time education specialists. There were no staffing changes during this year.

Administrative milestones:
- NSF EHR-DUE award (1914915) was made in September 2019 supporting the GETSI project providing field education support.
- An Intergovernmental Personnel Act (IPA) Agreement with USGS was secured in fall 2019. S. Olds serves as the ShakeAlert Geodetic Education Resources Coordinator working with the ShakeAlert Communication, Education, and Outreach (CEO) project to advance the development of geodetic-related science, engineering, and technology education resources that engage learners in a range of environments, from formal K-12 education to informal free-choice learning environments.
- Spring 2020 included shifts in project execution due to COVID-19 including cancellation or postponement of workshops, converting internship programs to remote models and moving all short courses to an online format.
Education (U3.2.1)

ECE education activities include all efforts to advance formal and informal education. The largest education curriculum initiatives are funded by separate awards from NSF:

The GETSI project (Geodetic Tools for Societal Impact (current awards: NSF EHR-1725347 and EHR-1914915) develops and disseminates teaching materials for engaging undergraduate students in addressing societally important Earth science questions through the use of geodetic data and methods in the classroom and field. The GETSI project materials include classroom and field-focused teaching modules. The GETSI materials are a part of the SERC website.

The GeoCode (NSF EHR-1841928) project is a partnership between UNAVCO, University of South Florida, and Concord Consortium and focused on developing coding experiences focused on geosciences for secondary level students. Through coding, students transform high-precision, real-world GPS data into interpretable visualization. The GeoCode project materials are a part of the Concord Consortium website.

ShakeAlert® earthquake early warning project includes the incorporation of geodetic resources (from GAGE) for use in formal and free-choice learning environments.

Additional activities of the GAGE Education team included:

- Short course at the 2019 GSA Annual Meeting. Preparing Undergraduates -- Data-Rich Introductory Teaching Modules and Connecting Content to Geoscience Careers.
- Earth Science Information Partners (ESIP) collaborations including 2019 K-12 teacher workshop, Data to Action with Jupyter Notebooks and other Earth Science Tools and a second in person teacher workshop in winter 2020. In addition a mini-grant was received for Developing Earth Science Data Tools for Educators: A Guidebook.
- SERC EDDIE (Environmental Data-Driven Inquiry & Exploration) undergraduate learning module development using NOTA data to facilitate student inquiry of earthquake zones.
- GAGE staff joint with National Association of Geoscience Teachers (NAGT) supported the conversion of teaching from in-person to online through a webinar series with over 1500 participants over 5 events.

Education Highlight: Educator workshop

Education Highlight: GETSI Field Kick-Off Meeting

Education Highlight: Geo-Code curriculum

Sample block programming language code using variables to simulate tephra distribution on a map along after a volcanic eruption. (Image/Concord Consortium)
GeoWorkforce Development (U3.3.1)

UNAVCO’s geoscience workforce development efforts provide opportunities for students in various stages of pursuing geoscience related careers. Three internship programs, early career support and related student activities are included. All UNAVCO internship programs were moved to a remote format with virtual programming due to the national COVID-19 restrictions.

The RESESS program (Research Experiences in Solid Earth Science for Students) is a research-focused internship program dedicated to increasing the diversity of students entering geosciences. Intern projects were with USGS staff in 2019 and 2020.

- 2019, eight undergraduate students participated in the RESESS internship program. They were supported by UNAVCO staff, 14 research mentors, and eight communications mentors. We estimate that these mentors dedicated over 1500 hours of time to supporting students, over the 11-week period.
- Seven RESESS interns from the 2019 cohort presented research posters at the AGU Fall meeting in San Francisco, California.
- RESESS Alumni dinner took place at the 2019 Fall Meeting of the AGU.
- 2020, six undergraduate students participated in the RESESS program (remote). All communication mentors were RESESS alumni.

The Geo-Launchpad program (GLP) (NSF ICER 1540524) is a paid summer internship program for Colorado and New Mexico students enrolled in community college. This pre-REU program helps students develop research-ready skills that they can take into an REU and professional development for their academic and professional career.

- 2019, six community college students participated in the GLP pre-REU program.
- All six GLP interns presented their summer projects at the GSA Annual Meeting.
- 2020, four community college students participated in GLP.

The UNAVCO Student Internship Program (USIP) is a work-focused internship. Graduate students work at the GAGE facility for 11-weeks during the summer.

- 2019, two graduate students participated in the program with the Geodetic Data Services Group (GDS); one was hired as a full time staff member.
- 2020, two graduate students participated working with GDS.

Additional activities:
- Early career/student networking luncheon at 2019 Fall Meeting of AGU. Joint with IRIS and SCEC it engaged 17 mentors and 55 students and early career attendees.
- Led a mentoring workshop at 2019 AGU Fall Meeting: How to be an Effective Mentor and Mentee.
- Exhibited at diversity-focused conferences with partner organizations as part of the Earth Science Convergence Zone:
  - National Association of Black Geophysicists (NABG) annual meeting.
  - Society for the Advancement of Native Americans and Hispanics/Chicanos in Science (SACNAS) conference.
  - SACNAS session Exploring Geoscience Pathways in Academia led by GAGE staff.

GeoWorkforce Development Highlight


GeoWorkforce Development Highlight:

Twelve interns from summer 2020 due to the COVID-19 pandemic (Photo/UNAVCO).
Short Courses (U3.4.1)
Short courses and professional development activities further the technical knowledge and skills of community members. Short courses and educational workshops are posted and archived online. Fifteen events were facilitated during this annual reporting period.

Short Courses Highlight:

Participants in the 2019 InSAR Theory and Processing short course. (Photo/B. Bartel, UNAVCO)

Short Courses Highlight:

Science communication workshop at University of South Florida. (Photo/M. Cook, USF)

Outreach and Communications (U3.5.1)
Outreach and communications include all activities related to educating non-GAGE community members about geodesy and geophysics as well as services provided by the GAGE facility.

The website is the primary mechanism community members use to obtain information and data from the GAGE facility. Social media including Facebook, Twitter, Instagram and YouTube engage the GAGE community, the broader geoscience community, and the general public.

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Website Visitors</th>
<th>Social Media Impressions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>67,051</td>
<td>631,205</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>67,942</td>
<td>404,150</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>68,221</td>
<td>446,548</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>61,888</td>
<td>392,966</td>
</tr>
</tbody>
</table>

Notable activities:
- Contributed to Yellowstone Caldera Chronicles posts as a partner of the Yellowstone Volcano Observatory (joint activity with GI).
- Developed NOTA and GAGE-branded materials including signage, brochures, stickers, note-pads, and banners to promote GAGE services.
- Coordinated a NOTA sticker for equipment enclosures in English and Spanish (joint with GI).
- Exhibited at the 2019 AGU Fall Meeting to network with the GAGE community.
- Developed co-branded presentation templates for GAGE-SAGE.
- Established Measuring Earth, a new Facebook page for a broad audience.

Highlight: 2020 GAGE/SAGE Calendar

The 2020 GAGE/SAGE calendar is a collaborative product with each month featuring how geophysical tools enable us to better understand our planet.
Highlight Y2Q2: GAGE-focused materials

Approximately 300 people participated including students, university faculty, IRIS and UNAVCO staff, and government employees. Planning was done collaboratively, with IRIS serving as the lead organization for logistics and budget.

- The 2020 GAGE-SAGE Community Workshop was scheduled for August 18-20, 2020 in Breckenridge, Colorado. Due to COVID-19, the workshop was postponed until August 2021. The planned program will carry over to 2021 and will be revisited and updated in spring 2021.

Education & Community Engagement

Synergistic Activities

Geo-Launchpad
- **NSF-ICER-1540524**.

GETSI-Classroom Phase 2
Collaborative Research: Implementing 21st century geodesy learning through faculty development and expanded applications of data to societal issues.
- **NSF-EHR-1725347**.
- $437,892; 08/01/2017-07/31/2020.
- ECE Personnel: D. Charlevoix, B. Pratt-Sitaula.

GETSI Field Phase 2
Collaborative Research: Broadening Use of Modern Geodetic Methods in Earth Science Field Courses.
- **NSF-EHR-1914915**.
- $491,614; 09/01/2019 – 08/31/2022.
- ECE Personnel: D. Charlevoix, B. Pratt-Sitaula.

GeoCode
CynerG: Integrating Computational Visualization with Exploration of Geohazards.
- **NSF-EHR-1841928**.
The GI program performs construction, operation and maintenance of permanent networks of GNSS and other instruments; coordination and execution of PI campaign projects and support of PI networks; development and testing of instrumentation, monuments, power systems and communications; and logistical support of all field operations for NSF-OPP PI projects.

**GI NSF-OPP Key Metrics**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Projects/Proposals Supported</th>
<th>Permanent Stations Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Arctic</td>
<td>Antarctic</td>
</tr>
<tr>
<td>2019 Jul-Sep</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

Notable activities:

**Y1Q4:**
- Successfully completed a significant GNET field maintenance effort, circumnavigating the island of Greenland. This work was performed under a full-cost recovery contract with the Danish Agency for Data Supply and Efficiency (SDFE).
- Tested, prepared, and shipped large amounts of equipment and supporting materials for the upcoming Antarctic field season (2019-2020).
- Geodetic Imaging team procured new airborne optical sensors, and UAS platforms to fly them on. A subset of these headed to Antarctica for supported field projects.

**Y2Q1:**
- Polar engineers traveled to Antarctica in late October to begin supporting the 2019-2020 Antarctic field season. 16 of the 21 projects were on the support schedule during this reporting period; the support season ended mid-February.
- Completed a significant ANET field maintenance effort, working from the Antarctic Logistics and Expeditions (ALE) camp at Union Glacier.
- Working with Danish Agency for Data Supply and Efficiency (SDFE) to draft a new full cost support agreement for 2020 GNET activities.
- Geodetic Imaging team procured new airborne multispectral optical sensors and UAS platforms to carry the sensors. A subset is currently in Antarctica for supported field projects.

**Y2Q2:**
- Antarctic field season effort finished in early Q2. A total of 21 PI projects were supported in Antarctica; 5 of those occurring in Y2Q2.
- Successfully negotiated with Danish Agency for Data Supply and Efficiency (SDFE) to draft a new full cost 2020 GNET activity support agreement.

**Y2Q3:**
- The Polar team provided content and backup materials for the joint GAGE/SAGE NSF review held in June 2020.
• Provided detailed input to US Antarctic Program planning efforts for the coming field season.
• Ongoing preparations continued for a GNET field season in Greenland. Logistics have been coordinated by the Denmark Technical University (DTU). This work is a full-cost recovery contract.

Issues/challenges:
Y1Q4:
• The Polar engineering team has seen a reduction in staff of two field engineers from a year ago. Search underway for one replacement.

Y2Q1:
• UNAVCO advanced offers to several qualified candidates, all of whom declined to accept an engineering position in Polar Services.

Y2Q2:
• One vacancy was filled in Polar Services this quarter, while a second remains open.
• COVID-19 responses globally have significantly impacted planned Arctic work. While most projects are on an uncertain delay, others have been canceled outright.

Y2Q3:
• One full-time vacancy was filled recently, while a second remains open.
• Continued issues with COVID-19 and planned field operations.

Resolved issues/challenges:
Y1Q4, Y2Q1: None to report.
Y2Q2, Y2Q3: Backfilled one of two open polar staff positions.

NSF-OPP Support - Arctic (U1.4.1)

GI support for OPP Arctic research programs includes engineering technical support to PI projects. Activities include campaign GNSS and terrestrial imaging projects; hands-on training courses to researchers; installation and O&M of permanent GNSS stations and associated power and telemetry systems including GNET, the Greenland component of POLENET through the close of Y2Q1; and postseason data processing and data archival support. GI maintains dedicated engineering and equipment resources for OPP due to the unique technical and logistical challenges associated with polar environments. OPP also requires coordinated field season planning and survey systems at various polar research stations.

A detailed list of supported NSF-OPP networks and PI projects is provided in Appendix B.

Notable activities:
Y1Q4:
• UNAVCO staff completed a significant GNET field season. Twenty-six stations were upgraded with new XEOS/Resolute receivers and all stations within the GNET network were visited in a marathon helicopter-supported effort. The GNET network continues its operational status with funding from the SDFE.
• Three new low-power XEOS/Resolute GNSS receivers were added to the Arctic pool.

Y2Q1:
• Discussions are underway with the Danish Agency for Data Supply and Efficiency (SDFE) to provide additional GNET support funding through the end of the current calendar year, 2020. Most of the work planned for late spring.
The low-power XEOS/Resolute GNSS receivers added to the GNET network continue to perform well. We are moving forward with plans to gradually integrate this GNSS instrument into the UNAVCO equipment pool to support PI projects.

Y2Q2:
- Coordinated with the Danish Agency for Data Supply and Efficiency (SDFE) to provide additional GNET support funding through the end of the 2020 calendar year. This external funding enables UNAVCO staff engineers to provide technical and field support to the project, in cooperation with the Technical University of Denmark (DTO). Despite COVID-19 limitations, preparations for a possible field season in August 2020 continue.
- Working with the NSF and investigators to plan around COVID-19 impacts to field season efforts.

Y2Q3:
- UNAVCO staff engineer continued to provide technical and field support planning to the GNET project, in cooperation with the Technical University of Denmark (DTU). Despite COVID-19 limitations, preparations continued for a likely field season in August 2020.
- Continued to work with the NSF and PIs to plan around COVID-19 impacts to field season efforts, including standing ready to prep and ship gear on short notice.

Issues/challenges:
Y1Q4, Y2Q1, Y2Q2, Y2Q3:
- See staffing discussion above.

Y2Q3:
- COVID-19 responses globally impacted planned Arctic work. While some projects remain on an uncertain delay, most have been canceled outright.

Resolved issues/challenges:
Y1Q4, Y2Q1, Y2Q3: None to report.
Y2Q2: One staff position filled.
NSF-OPP Support - Antarctic (U1.4.2)

GI support for OPP Antarctic research programs includes engineering technical support to PI projects. Activities include campaign GNSS and terrestrial imaging projects; hands-on training courses for researchers; installation and O&M of continuously operating GNSS stations and associated power and telemetry systems including ANET, the Antarctic component of POLENET; and postseason data processing and data archiving support. GI maintains dedicated engineering and equipment resources for OPP due to the unique technical and logistical challenges associated with polar environments. OPP also requires coordinated field season planning and survey systems at various polar research stations.

### Antarctic PI Proposals/Projects - GNSS

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Proposals</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

### Antarctic PI Proposals/Projects - Imaging

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Proposals</th>
<th>Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

### Antarctic GNSS Permanent Network O&M

<table>
<thead>
<tr>
<th>Time Period</th>
<th>ANET Stations</th>
<th>ANET Site Visits</th>
<th>Antarctic PI Stations</th>
<th>Antarctic PI Site Visits</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>33</td>
<td>0</td>
<td>69</td>
<td>0</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>33</td>
<td>12</td>
<td>69</td>
<td>5</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>33</td>
<td>0</td>
<td>69</td>
<td>2</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>33</td>
<td>0</td>
<td>69</td>
<td>2</td>
</tr>
</tbody>
</table>

### Antarctic GNSS PI Receiver Pool

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Modern (&lt;5 years old) Receivers</th>
<th>Receivers in Pool</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>14</td>
<td>220</td>
<td>53%</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>14</td>
<td>220</td>
<td>65%</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>14</td>
<td>220</td>
<td>65%</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>14</td>
<td>220</td>
<td>51%</td>
</tr>
</tbody>
</table>

A detailed list of supported NSF-OPP networks and PI projects is provided in Appendix B.

Notable activities:

**Y1Q4:**
- Significant time spent planning and preparing equipment for the upcoming Antarctic season. Equipment and supplies were tested and shipped in support of 23 anticipated projects.
- Three new low-power XEOS/Resolute GNSS receivers were added to the Antarctic equipment pool this quarter.

**Y2Q1:**
- Significant time spent on integration, final testing, and preparation of equipment for 2019-2020 Antarctic field projects. Equipment and supplies were shipped for 21 scheduled PI projects.
- New optical sensors, including hyperspectral and thermal imaging cameras, were procured for the Geodetic Imaging UAVs. A subset was brought to Antarctica to be flown at selected Long Term Ecological Research (LTER) study sites.
- PI team for ANET and a UNAVCO engineer visited 15 sites in the remote West Antarctic, performed site maintenance, replacing aging receivers with new Resolute GNSS instruments.
- Renewal plan to replace the aging polar equipment pool is underway, as new generation GNSS receivers are identified and tested. New Resolute GNSS receivers will replace the bulk of our Trimble NetRS and NetR9s as we move forward. We are also reviewing low-cost kinematic receivers.

**Y2Q2:**
- Completed the remainder of the Antarctic field season, based out of both McMurdo Station and Union Glacier (ANET). 21 PI projects were supported from October 2019 to February 2020.
- IRIS/PASSCAL facility team members and UNAVCO polar staff met at UNAVCO for a joint planning meeting. The teams discussed how to better collaborate on equipment designs and other work offered to the PI community.
- Testing to replace aging reference and kinematic receivers with new generation GNSS receivers continued. The multi-constellation campaign kinematic receiver, STONEX-S900, performed favorably and has a modest price point.

**Y2Q3:**
- COVID-19 impacts on 2020 Antarctic field science scope. UNAVCO spent significant time drafting planning documents for a deep field mission to recover over 40 instruments to the surface of the Thwaites Glacier, secure data, and reset them to run for an additional year.
Issues/challenges:
Y1Q4, Y2Q1, Y2Q2: See staffing issues above.

Y1Q4:
● Ongoing issue: Large numbers of existing polar GNSS pool instruments are no longer supported, are becoming unreliable, and lack support for full-GNSS satellite constellations. Renewal plan is underway as new generation GNSS receivers are identified and tested.

Y2Q1:
● ParoScientific Weather instruments to be co-located with ANET sites are failing in the field at unacceptable rates. Lengthy environmental chamber and benchtop testing prior to deployment uncovered no issues. Static electricity generated by high winds, extreme low temperatures, and blowing snow is being investigated as possible causes.

Y2Q2:
● Performance issues with ParoScientific Weather continue to be investigated. Several failed devices are returning from the field, and a plan to address the issues with the manufacturer was developed.

Y2Q3:
● A plan to address the issues with the manufacturer of ParoScientific Weather instruments recently co-located at a number of ANET sites has been implemented.
● COVID-19 will seriously curtail field activities in Antarctica for at least the next year. UNAVCO is participating in contingency planning with multiple stakeholders, as the USAP scope evolves.

Resolved issues/challenges:
Y1Q4, Y2Q1: None to report.
Y2Q2-Y2Q3: Successfully filled one of two open positions.

NSF-OPP Antarctic Highlight Y1Q4: ANET status.

NSF-OPP Antarctic Highlight Y2Q1: GNSS-IR experiment

Resolute GNSS receiver WILZ, used for reflectometry experiment was installed on the McMurdo Ice Shelf (Photo/J. Pettit, UNAVCO)

NSF-OPP Antarctic Highlight Y2Q2: Work was performed at the Fishtail Point cGPS, FTP4 in Antarctica to deploy point to point radio telemetry.

cGPS site visit to FTP4 at Fishtail Point in Antarctica. (Photo/ K. Williams, UNAVCO)

NSF-OPP Antarctic Highlight Y2Q3: In an effort to update the receiver pool, the UNAVCO Polar staff has been evaluating new generation, low cost GNSS kinematic solutions, including the fully integrated and RTK enabled STONEX-S900 receiver.

The STONE S900 GNSS kinematic receiver. (Photo/STONEX)

Map showing ANET station locations as of Y1Q4.
GNSS Data

The GDS portfolio benefits all CSAs. GDS support for OPP GNSS data is supported by the EAR CSA (1851159). GDS supports data network operations, archiving, curation and distribution for all OPP GNSS stations and generates data products as described in the NSF-EAR U2.2 section of this report.

### OPP GNSS Network Data Return

<table>
<thead>
<tr>
<th>Time Period</th>
<th>ANET</th>
<th>GNET</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>89%</td>
<td>91%</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>84%</td>
<td>90%</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>86%</td>
<td>90%</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>89%</td>
<td>90%</td>
</tr>
</tbody>
</table>

Data return: % data files delivered versus expected; delivery of all expected data equals 100% data return.

### OPP GNSS Data Archived/Delivered

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Archived (GB)</th>
<th>Delivered (GB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>114</td>
<td>482</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>94</td>
<td>784</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>89</td>
<td>829</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>87</td>
<td>651</td>
</tr>
<tr>
<td>Total since 2013-10</td>
<td>3202</td>
<td>11091</td>
</tr>
</tbody>
</table>

Map showing Antarctic GNSS stations with Level 2 data products (position time series, velocities, etc.) generated for GAGE by CWU and MIT subawards.

Map showing Arctic region GNSS stations with Level 2 data products (position time series, velocities, etc.) generated for GAGE by CWU and MIT subawards.

**Education & Community Engagement**

Education and Community Engagement (ECE) includes a continuum of activities and areas of responsibility including: community engagement activities, education, outreach, workforce development, and technical short courses and other professional development.

The ECE portfolio benefits all aspects of the GAGE Facility (EAR, OPP, and NASA). See section CSA EAR–1851159: NSF-EAR for ECE GAGE contributions.
NASA

Geodetic Infrastructure

UNAVCO operates and maintains the NASA Global GNSS Network (GGN) to support global geodesy. Network operations support the global GPS/GNSS network underlying the internationally coordinated reference frame products that make high-precision global geodesy possible.

NASA GI Support (U4.1)

<table>
<thead>
<tr>
<th>Time Period</th>
<th>NASA GGN Stations Monitored</th>
<th>NASA GGN Receivers Monitored</th>
<th>NASA GGN Trouble-shoots</th>
</tr>
</thead>
<tbody>
<tr>
<td>2019 Jul-Sep</td>
<td>62</td>
<td>65</td>
<td>118</td>
</tr>
<tr>
<td>2019 Oct-Dec</td>
<td>62</td>
<td>65</td>
<td>159</td>
</tr>
<tr>
<td>2020 Jan-Mar</td>
<td>62</td>
<td>65</td>
<td>86</td>
</tr>
<tr>
<td>2020 Apr-Jun</td>
<td>62</td>
<td>65</td>
<td>111</td>
</tr>
</tbody>
</table>

Data return: % data files returned versus expected; delivery of all expected data equals 100% data return.

GGN Engineering (U4.1.1) and O&M (U4.1.2)

GI engineering support to NASA GGN includes management, upgrading of continuously operating GNSS stations around the world, and installation of new stations when required. Activities include basic operations, budget management, hardware and computer configuration and shipping, coordination with local station operators, and field visits. O&M is a non-labor task that contains fieldwork-related travel, materials, and communications expenses. UNAVCO operates the GGN in close coordination with the JPL Program Manager and NASA HQ Program Directors.

Map showing the operational state of the NASA GGN as of June 30, 2020. Green: Station is operational. White: Station is offline or not publishing data.

Notable activities:
Y1Q4:
- A memorandum of understanding was completed and signed with the Federal University of the Northern Rio Grande, the station hosts for NATL in Natal, Brazil. The formalized agreement will allow UNAVCO to proceed with the long-awaited duty-free shipment of new GNSS equipment into Brazil. The site is one of the last stations in the network with a GPS-only receiver.
- A severe lightning storm affected all stations at the Texas McDonald Observatory site: MDO1,
MG02, MG03, MG04, and MG05. All five antennas and four receivers were replaced during a site visit. Only one out of all the installed gas cap EMP suppressors had popped despite proper grounding.

Y2Q1:
- A new campaign was initiated to replace older generation GNSS receivers in the GGN with state-of-the-art Septentrio PolaRx5 receivers capable of tracking all modern satellites and signals. Four were replaced during Y2Q1.
- New Septentrio PolaRx5 receivers were sent to stations SANT (Santiago, Chile), AREQ (Arequipa, Chile), and MDO1 (McDonald Observatory, TX) as part of the ongoing receiver upgrade campaign. The receivers for SANT and AREQ have not been installed due to initial delays by the station hosts, and more recently the COVID-19 outbreak.
- The newly installed MDO1 receiver is operational.

Y2Q3:
- UNAVCO has been testing a new computer system for deployment at GGN stations: the Lenovo M90N, a powerful small form factor machine. These deployments are part of an upgrade the GGN station servers to modern CentOS7 operating systems, which host JPL data software. Many GGN servers currently run on CentOS6, which will reach end-of-life in Nov. 2020.
- UNAVCO staff overhauled and restructured the file systems of the server that hosts all GGN-related information (hardware, field reports, photos, etc). This server provides critical information for JPL and its contractors, who access it directly.

Issues/challenges:
Y1Q4: None to report.

Y2Q1:
- For the past 1.5 years, UNAVCO has been collaborating on a new MoU with the University of California, San Diego (UCSD) and the Chilean Nuclear Energy Commission (CChEN). CChEN operates a seismic station on Easter Island where both UNAVCO and UCSD have equipment co-located (IGS station ISPA). In December 2019, we learned that the MoU was formally rejected. The station currently remains offline.

Y2Q2:
- Station SEY2 in the Seychelles islands had been experiencing ongoing challenges with regular communications outages throughout the Fall of 2019, and into the first half of the reporting period. The issue lies with the ISP. Although resolved in early March, 5 days later, it resumed. The GNSS receiver continues to track locally.
- Field testing of the RF-fiber optic system at station MG03 (an important station at McDonald Observatory, TX and part of the NASA Space Geodesy Project) has revealed problems with satellite tracking that may be linked to bad fiber cabling. Troubleshooting has been challenging due to COVID-19 travel restrictions and our reliance on onsite staff to help troubleshoot.

Resolved issues/challenges:
Y1Q4:
- Station GUAM was brought back online after a multi-month outage, requiring the replacement of the receiver, computer, and network switch.
- After extensive troubleshooting was carried out with local collaborators at station YKRO in the Ivory Coast, the internet problems were resolved and the station was restored to full operations after a communications outage lasting over a year. Data had been logged on the receiver and has been retrieved and archived.
- MG02 at McDonald Observatory lost all tracking after a brief period of deteriorating performance. The fault was identified as water ingress within an EMP suppressor and eventual corrosion of the center conductor. This was replaced and normal tracking resumed.

Y2Q1: None to report.

Y2Q2:
- At station ZAMB in Lusaka, Zambia, a local contractor was engaged to relocate the receiver, computer, and UPS from an enclosure on the roof of the building where the antenna is located to the building’s server room, where reliable power and internet are now available. Problems with power, internet connectivity, and TCP port blockage had been ongoing throughout 2019.
- IGS reference frame station PIE1 in Pietown, NM lost tracking in May 2020 due to a variety of issues with the station receiver, backup power, and the RF signal splitter. Collaborative troubleshooting with local staff allowed much of the hardware at the site to be replaced, yielding a return to normal data flow in June 2020.
NASA GGN Highlight Y1Q4: McDonald Geophysical Observatory, TX (MGO)

Overview of all the Texas MGO stations (except RTS2) shown in this view) that were affected by the lightning storm that occurred mid-September 2019.

NASA GGN Highlight Y2Q1: Station MKEA, National Radio Astronomy Observatory (NRAO) facility, Maunakea, Hawaii

GNSS station MKEA had been experiencing signal quality issues, showing a steady decline in SNR and position errors over an extended period. UNAVCO engineer Jacob Sklar and Dave Stowers of JPL visited the site in mid-December to replace the old antenna cable with 82 m of low loss LMR-600 and install a new Septentrio PolaRx5 receiver. The new cable resulted in improved signal quality. (Photo/UNAVCO)

NASA GGN Highlight Y2Q2: Station MGO3 is one of six GNSS stations located at the McDonald Observatory near Fort Davis, Texas, and a component of NASA’s Space Geodesy Project. It is in a lightning prone environment and has suffered from several indirect lightning strikes since its installation in 2017. In February 2020, an RF-to-fiberoptic system was deployed between the antenna and receiver to mitigate this problem. Fiber optic cable is not affected by lightning, protecting the GNSS receiver and data download computer from ground surges, although the antenna remains vulnerable. The system will undergo field testing for several months before similar fiber optic systems are deployed at the other GNSS stations at the observatory.

MGO3 - A fiber optic transmitter unit (pictured foreground) is located in an outdoor solar-powered enclosure, at a short distance from the GNSS antenna. (Photo/UNAVCO)
Geodetic Data Services

The GDS program manages a complex set of data, metadata and data flow systems, providing a wide range of geodetic/geophysical observations to scientific and educational communities.

NASA GDS Support (U4.2)

GDS provides support to the NASA Global Geodetic Network (GGN) (U4.2.1), the IGS Central Bureau (U4.2.2) and WinSAR (U4.2.3).

GGN (U4.2.1)

GDS support to the NASA Global Geodetic Network (GGN) includes troubleshooting of data and metadata flow, identification and correction of metadata issues and metadata management for the GGN, and software applications and development for support to the global GNSS community.

Notable activities:
- Y1Q4, Y2Q1: None to report
- Y2Q2: Operational metadata for the GGN is being integrated into the GDS Metadata Management System (MDM) to facilitate operations of the network.
- Y2Q3: Operational metadata for the GGN continues to be integrated into the GDS Metadata Management System (MDM) to facilitate operations of the network.

Issues/challenges:
- Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.

Resolved issues/challenges:
- Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.

IGS Central Bureau (U4.2.2)

GDS support to the International GNSS Service (IGS) Central Bureau (IGSCB) includes troubleshooting of data and metadata flow, identification and correction of metadata issues and metadata management, operational support for information dissemination to the IGS community, software support for metadata management and data access including the IGS Site Log Manager system. Information technology support is provided for the IGS Central Bureau web site. The GDS Director is currently also on the executive committee of the IGS Governing Board and the Data Center project manager is on the IGS Governing Board.

<table>
<thead>
<tr>
<th>NASA IGSCB Support</th>
<th>Time Period</th>
<th>Site Log Updates</th>
<th>Stations Added</th>
<th>Stations Decommissioned</th>
<th>Issues Worked</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2019 Jul-Sep</td>
<td>103</td>
<td>2</td>
<td>2</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td>2019 Oct-Dec</td>
<td>138</td>
<td>0</td>
<td>1</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>2020 Jan-Mar</td>
<td>249</td>
<td>3</td>
<td>0</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>2020 Apr-Jun</td>
<td>132</td>
<td>0</td>
<td>1</td>
<td>29</td>
</tr>
</tbody>
</table>

Notable activities:
- Y1Q4:
  - GDS Director Meertens attended the IGS Governing Board meeting in Montreal, Canada, on July 15.
  - Provided general IGS support including IGS network coordination.
  - IGS Executive Committee monthly conference calls (Meertens).
  - IGS website upgraded with new map showing stations and helping with transition to AWS.
  - UNAVCO and UCAR will be hosting the IGS Workshop in August, 2020. Meeting organizers Meertens and Braun met with UCAR’s CPASESS group to look into the possibility for them to provide the meeting logistics support.
- Y2Q1:
  - GDS Director Meertens, F. Blume, and D. Maggert participated in the IGS Governing Board meeting held on Sunday prior to the AGU Fall 2019 meeting in San Francisco, California.
  - F. Blume, chair of the Scientific Organizing Committee for the IGS 2020 Workshop, presented preliminary workshop plan to the IGS Governing Board and Associate members.
○ C. Meertens and John Braun (UCAR) are chairing the local organizing committee for the IGS 2020 Workshop.

- Provided general IGS support including IGS network coordination.
- IGS Executive Committee monthly conference calls (Meertens).
- IGS Site Support:
  ○ Completed website move to AWS.
  ○ Implemented online station map interface.
  ○ Developing new station pages for IGS site.

Y2Q2:

- Provided general IGS support including IGS network coordination.
- IGS Executive Committee monthly conference calls (Meertens).
- GDS staff have been working with JPL IGS Central Bureau to implement the new IGS web page.

Y2Q3:

- Provided general IGS support including IGS network coordination.
- IGS Executive Committee monthly conference calls (Meertens).
- GDS staff have been working with JPL IGS Central Bureau to implement the new IGS web page.

Issues/challenges:

Y1Q4, Y2Q3: None to report.

Y2Q1:

- IGS Boulder Workshop Scientific Organizing Committee planning activities will require significant GITS staff time between now and the August workshop.

Y2Q2:

- The IGS 2020 Workshop originally scheduled for August 8, 2020 has been postponed until a later date in 2021.

Resolved issues/challenges:

Y1Q4, Y2Q1, Y2Q2, Y2Q3: None to report.

WInSAR (U4.2.3)

GDS data technicians operate and maintain systems critical for data products and services for WInSAR, perform data quality assurance, help develop and maintain tools and services, and create the metrics for tracking and reporting. Software engineers develop and maintain tools for the community such as web services to provide easier access to and presentation of geodetic data to meet evolving needs for data products as well as web enhancements for documentation and additional entry points to services and displays. Software engineers develop InSAR products such as interferograms and tools to manage and visualize such products. Software Engineer Scott Baker also participates in developing and teaching SAR processing short-courses. WInSAR support is an integrated part of overall SAR activities described in the NSF-EAR section of this report.

Notable activities:

Y1Q4, Y2Q2, Y2Q3: None to report.

Y2Q1:

- UNAVCO organized the WInSAR business lunch held during the AGU Fall 2019 Meeting in San Francisco, California.

Education & Community Engagement

Education and Community Engagement (ECE) includes a continuum of activities and areas of responsibility including: community engagement activities, education, outreach, workforce development, and technical short courses and other professional development.

NASA Education and Community Engagement CE (U4.3.1)

The ECE portfolio benefits all aspects of the GAGE Facility (EAR, OPP, and NASA). See section CSA EAR–1851159: NSF-EAR for ECE GAGE contributions.