Commercial Satellite Data Acquisition Program

Capella Space Principal Investigator Evaluation Summary

Goddard Space Flight Center
Greenbelt, MD

Commercial Satellite Data Acquisition Program Capella Space Principal Investigator Evaluation Summary

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Preface

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Abstract

The evaluation summarized in this report was conducted by Principal Investigators (PIs) funded by NASA's Commercial Satellite Data Acquisition (CSDA) Program. The purpose of evaluation is to determine the utility of the Capella Space data for NASA Earth science research and applications community. The results of the evaluation help inform NASA program management on the ability of the data to further augment NASA science.

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Executive Summary

NASA's Earth Science Division (ESD) Commercial Satellite Data Acquisition (CSDA) program selected 13 principal investigators (PIs), along with their teams, via a call for proposals under the NASA Research Opportunities in Space and Earth Science (ROSES) solicitation, to evaluate Capella Space (also referred to here as Capella) as part of the third CSDA on-ramp. Capella Space develops and manages a constellation of X-band synthetic aperture radar (SAR) instruments that provide high spatial resolution, frequent revisit, and reduced data delivery latency views of the Earth's Surface. Capella launched their first satellite, "Denali," in 2018. At the beginning of this evaluation Capella had 7 satellites in orbit and launched another satellite during the evaluation. Three Capella Space satellites de-orbited in the first half of the evaluation period, limiting access to high latitude regions. During this CSDA evaluation, 13 teams participated in evaluating Capella data across a spectrum of Earth science disciplines, including Solid Earth, Cryosphere, Water Resources, Ecosystems and Natural Hazards.

Evaluation teams were provided access to the Capella archive of previously acquired scenes dating back to 2020. In addition to accessing data through the archive, CSDA evaluation teams were also able to task the Capella constellation for new acquisitions. This tasking allowed several evaluation teams, especially those studying natural hazards, to test the utility of Capella data in workflows that may be more time sensitive. It also allowed evaluation teams to have the flexibility to acquire data in areas of interest that were seeing change or responding to environmental conditions (i.e., harmful algal blooms).

The vendors participating in the CSDA Program are evaluated on the accessibility of vendor supplied data, accuracy and completeness of metadata, quality of user support services and documentation, usefulness of the data for advancing Earth system science research and applications, and the quality of vendor supplied data. Datasets purchased during the evaluations are archived by NASA, and after the conclusion of the evaluations, the evaluated data are made available to current and future government-funded researchers in accordance with the end user licensing agreement (EULA). The scientists evaluated the Capella Space data in the context of a variety of research topics (see Table 2 and the Appendix).

The Capella Space evaluation kicked off with a first team meeting in March of 2023 and the team began formulating their data needs. Delivery of initial imagery products requested by the researchers began in Spring of 2023. This synthesis report distills and integrates the findings of evaluation research reports commissioned by NASA for the Capella evaluation. This report also includes recommendations that inform the way ahead for the program.

The evaluations found several strengths and weaknesses of these data for use in NASA Earth system science and applications investigations. Specifically, noted strengths of the Capella data from a consensus of investigation teams in all disciplines included:

1. Very fine spatial resolution (0.5 m) exceeds that of data currently available from platforms operated by various agencies.
2. Some, but very few, repeat data sets over the same area are available in the archive
3. Tasking for supported products works well
4. User support team is very responsive

Some of the common weaknesses that were found with Capella data included:

1. Lack of transparency and documentation for data quality and algorithms
2. Limited coverage available from vendor archive
3. No polar coverage during a large portion of the evaluation due to loss of satellites
4. Small scene size limits applications requiring large areal coverage.

The investigators found that the Capella data were largely useful and beneficial to many research and application areas. Most were extremely positive in their reviews regarding access to high spatial resolution X-band SAR data and the ability to task acquisitions for their specific work. The design of Capella's constellation enables rapid repeat coverage over an area of interest, which is highly valuable for Geohazards, as well as other research. Six of the 13 research teams reacted positively about the rapid revisit capabilities of the Capella constellation, while a few teams found it lacking. The evaluation teams found the Capella customer support team to be highly responsive during the evaluation.

Nearly all the evaluation teams noted geolocation issues with the Capella Space data. The geolocation issues ranged from a few meters to 100’s of meters. The investigators found that the small scene size of the Capella footprint restricted studies to very localized areas and are not well suited to regional or global assessments but still are useful for local process studies.

Several investigations suffered from non-repeating ground tracks and the lack of a true algorithm theoretical basis document (ATBD). Evaluations that required interferometric data were also challenged by the lack of Interferometric SAR (InSAR)-quality commercial products, and were limited to opportunistic, experimental products made available by the vendor. Several teams tried to use the Compensated Phase History Data (CPHD) products, but these data had spectral window functions applied, making the data difficult to interpret. Capella assisted several evaluation teams that were hoping to evaluate the utility of InSAR by providing several previously acquired repeat data stacks (repeat imagery collected over the same area of interest with similar imaging geometry), but there were few scenes available, and lack of access to raw data products constrained what could be accomplished. Even though the Capella InSAR products were not available commercially, there was a great interest expressed by the evaluation teams for interferometric data and they recommend that NASA and the CSDA Program find ways to make more InSAR capable data accessible in the future.

1. Background

NASA’s ESD formalized the CSDA program in 2020, following the successful Private-Sector Small Constellation Satellite Data Product Pilot that concluded that year. The objective of the CSDA program is to identify, evaluate, and acquire commercial remote sensing data that support NASA’s Earth science research and application activities. When the Pilot transitioned into the sustained CSDA Program, on-ramping opportunities were released for new vendors with the idea of expanding and enlisting new commercial vendors as the industry expands with new candidates and capabilities. NASA's ESD recognizes the potential impact commercial satellite constellations may have in encouraging and enabling efficient approaches to advancing Earth system science and applications development for societal benefit.

In addition to the Pilot, NASA has conducted two evaluations since the Pilot, these included two vendors in On-Ramp 2 and four vendors in On-Ramp 3. Capella Space was part of On-ramp 3, and the three other vendors in this on-ramp were wrapping up their evaluation activities in a similar timeframe.

NASA moved into a sustainment phase for the vendors from the Pilot and On-Ramp 2 with data collected by these vendors made available to NASA and other government funded researchers, according to the EULAs. More information can be found on the CSDA web site, under Commercial Datasets. The table below shows the vendors that NASA has engaged with for commercial data evaluations thus far.

Table 1. CSDA Evaluation Activities.

Evaluation Effort	Vendor	Type	Report Delivery
Pilot	Maxar	Optical	Apr 2020
	Planet	Optical	
	Spire	Radio Occultation	
On-ramp 2	Airbus U.S.	SAR	Oct 2023
	BlackSky	Optical	Jun 2024
On-ramp 3	GHGSat	Optical	Aug 2024
	Capella Space	SAR	Dec 2024
	ICEYE U.S.	SAR	Dec 2024
	GeoOptics	Radio Occultation	Oct 2024
IDIQ On-ramp 1	Umbra	SAR	Aug 2025
	PlanetiQ	Radio Occultation	Aug 2025

The vendors were evaluated on the accessibility of data, accuracy and completeness of metadata and documentation, promptness and quality of user support services, and usefulness of the data for advancing Earth system science research and applications. NASA's CSDA Program license agreements were expanded following the Pilot to broaden the applicability of the commercial data for scientific applications across the U.S. Government. These license uplifts made the data more readily available across the government and improved both the value of these data and the opportunities for interagency collaboration. In addition, NASA has engaged in separate dedicated evaluation activities to assess the satellite data quality of each vendor.

Results from the Pilot and the On-ramp 2 evaluations are available from the CSDA website. The final summary reports for all the On-ramp 3 evaluations will also be published on the CSDA web site upon completion and review of the evaluation reports.

1.1 On Ramp 3

On-ramp 3 was initiated in October 2022 with a request for information (RFI) seeking capability statements from the parties interested in providing data from spaceborne platforms for evaluation. To be responsive to the RFI, the commercial satellite data vendors had to be U.S. companies with one or more spacecraft actively collecting data in low, medium, or geostationary Earth orbits with a minimum of near-continental-scale coverage. Four vendors satisfied the RFI requirements and were asked to respond to a request for proposal. After review of the submitted proposals, NASA

entered into a Blanket Purchase Agreement with Capella Space in June 2023. The vendors evaluated during On-ramp 3 are listed in Table 2.

Table 2. The vendors and sensor information for On-ramp 3 evaluations (constellation numbers shown reflect status during the evaluation).

Vendor	Sensor Type	Temporal Coverage	Spatial Coverage	Satellites	Bands	Spatial Resolution
GHGSat	Optical	Jan 2021 - present	Global	10	1630 – 1675 nm	< 30 m
GeoOptics	GNSS-RO	Nov 2018 – Jan 2022	Global	0	L - Band	~100 km horizontal, ~100 m vertical
Capella Space	SAR	Jan 2021 - present	Global*	4 - 7	X - Band	0.5 - 11.5 m
ICEYE US	SAR	Oct 2019 - present	Global	13 - 21	X - Band	1 - 15 m

**During the evaluation period, Capella lost its only polar orbiting satellite sensor, thus access to data over areas beyond 48.9 deg N/S were limited.*

1.2 Capella Space Imaging Capabilities and Products Evaluated

Capella operated a constellation of 4-7 satellites during the CSDA evaluation period. These sensors collect data in 4 imaging modes, 3 Spotlight modes and a Stripmap mode. Data were available in several product formats, including ellipsoid corrected (GEC) and geocoded (GEO) images, single look complex (SLC) images, and CPHD preprocessed raw data.

Table 3. The specifications of the Capella Space data that investigators had access to (from information provided to the CSDA Program).

Capella Space SAR Products			
Priority Ordering Tiers	1-Day, 3-Day, 7-Day		
Orbits	45° INC, 53° INC, 97° SSO		
Collection Geometries	Ascending, Descending, Left, Right		
Imaging Modes	Spotlight (SP)	Sliding Spotlight (SS)	Stripmap (SM)
Scene Lengths	5 km	10 km	10 km - 100 km
Scene Widths	5 km	5 km	5 km - 10 km
Look Angle Range	5 - 40 deg	5 - 45 deg	5 - 45 deg
Azimuth Resolution	0.5 m	1.0 m	1.2 m
Slant Range Resolution	0.3 m	0.5 m	0.75 m
Ground Range Resolution	0.5 m - 3.1 m	0.7 m - 5.0 m	1.1 m - 11.5 m
Number of Looks	1 to 5	1 to 5	1

CSDA evaluation teams submitted orders to the Capella customer support team through a web order form and the data were delivered online through the Capella Console. The ordering system for standard products was usable, but for the lower level (i.e. CPHD) products direct interaction with Capella engineers was necessary. InSAR-quality pairs could not be ordered directly because the metadata available through the Capella Console did not include orbit information. This orbit information was only available in the extended metadata after the purchase and subsequent download of the product.

New tasking and archived Capella products were delivered in various product formats starting from the lower level CPHD format to the easier to use geocoded (GEC or GEO) data and this flexibility allowed some evaluation teams to utilize the format that was best for their research/application areas and workflows.

2. Evaluation Process and Criteria

NASA ESD selected 13 projects for the Capella evaluation. A subject matter expert (SME) team was also funded by CSDA to perform a quality assessment of the Capella data (the investigation teams are listed in Appendix A).

Seven of the investigations were related to ocean surface, coastal or surface water-related processes. Cryospheric processes were the focus of two investigations. Three investigations dealt with natural hazards and InSAR data assessment. Soil or agricultural applications were investigated by two of the evaluation teams. The evaluation Principal Investigators (PIs) provided interim, midterm, and final surveys and reporting, and attended monthly discussions to ensure they had sufficient information and data access to complete their evaluations.

2.1 Evaluation Criteria

The CSDA program provided evaluators the following categories for reporting on their findings from the Capella Space data evaluation for both the quality and utility of the data.

A. Access, Metadata and Support

I. Accessibility and format of vendor supplied data.

The ease and efficiency with which data can be searched, discovered, and downloaded from vendor systems.

II. Accuracy and completeness of metadata

The accuracy and completeness of metadata that accompanies the imagery and data provided by the vendor.

III. Quality of support services, including documentation

The availability, responsiveness, and technical expertise required to answer PI inquiries.

B. Usefulness of the data for advancing Earth system science Research and Applications

The ability of vendor-supplied data to support Earth system science Research and Applications

C. *Quality of Vendor Supplied data*

The quality of data attributes, such as radiometric calibration, geolocation accuracy, and platform intercalibration.

2.2 Program Activities

The evaluation was facilitated by conducting periodic reviews and surveys, PI all-hands, and monthly technical interchange meetings. The project timeline is depicted in Figure 1.

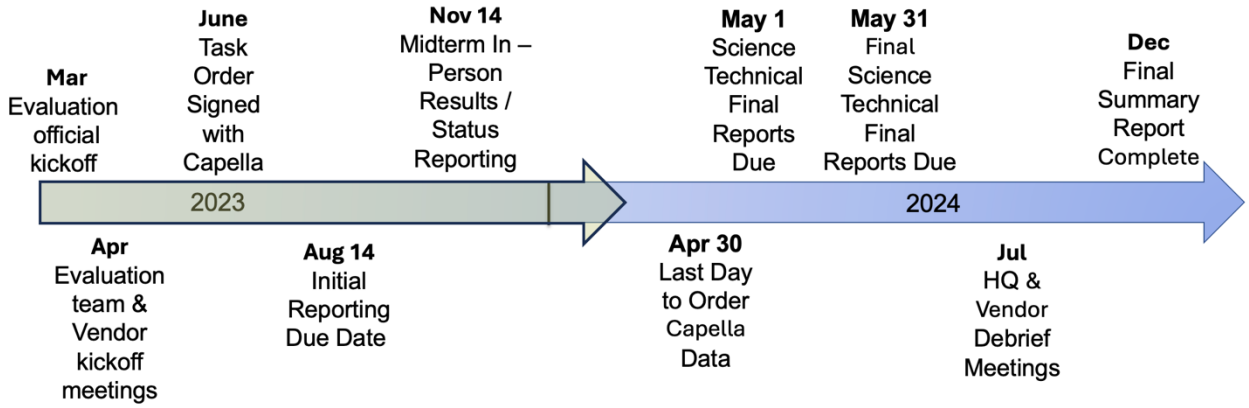

Figure 1. Timeline of Evaluation activities since awarding the purchase agreement.

2.3 Meetings, Periodic Reviews and Surveys

In addition to the team and vendor kick-off meetings, evaluation PIs were required to participate in periodic reviews and report on the usefulness of the data and current research progress. The PIs were asked to submit quad charts at three points during the evaluation, the first one shortly after gaining access to the data, the second at the evaluation midpoint, and lastly as part of their final submission. An in-person midterm meeting was held at the Goddard Space Flight Center that allowed the PIs to share their preliminary results and exchange information. All reports and surveys were synthesized in the creation of this final summary report.

2.4 Monthly Technical Interchange Meetings

Monthly conference calls were set up to facilitate technical interchange among the evaluation teams and with CSDA staff to help identify and resolve issues related to data access, quality, completeness, and processing. The teams were asked to identify issues and share information that might be relevant to other teams. The conference calls were set up as a means by which to ensure timely identification and prompt resolution of issues that might arise. These meetings also allowed

the CSDA staff an opportunity to gather and relay any concerns that the team may have to the vendor to accelerate resolution of any potential problems.

2.5 Community Engagement and Feedback

As the capabilities and numbers of commercial vendors grow, it is important to continuously monitor the development of new commercial technology, acquire relevant data to complement existing and future missions, and evaluate these data over time. The CSDA team continues to provide status updates, answer questions about data and data access, and provide information about future procurement opportunities for other commercial constellation providers at various science conferences and workshops. These community engagements serve as an open forum for dialogue between experts across the science data research community and help to showcase NASA's progress and commitment to building stronger ties to the commercial sector.

3. Key Findings

The key findings from this evaluation are organized into five general scientific areas that are aligned with corresponding Earth Science Division Programs. This evaluation was focused on assessing the utility of Capella Space data for advancing NASA's Research and Analysis and Earth Action focus areas. A summary of the different programs represented by the evaluation team members is shown in Figure 2.

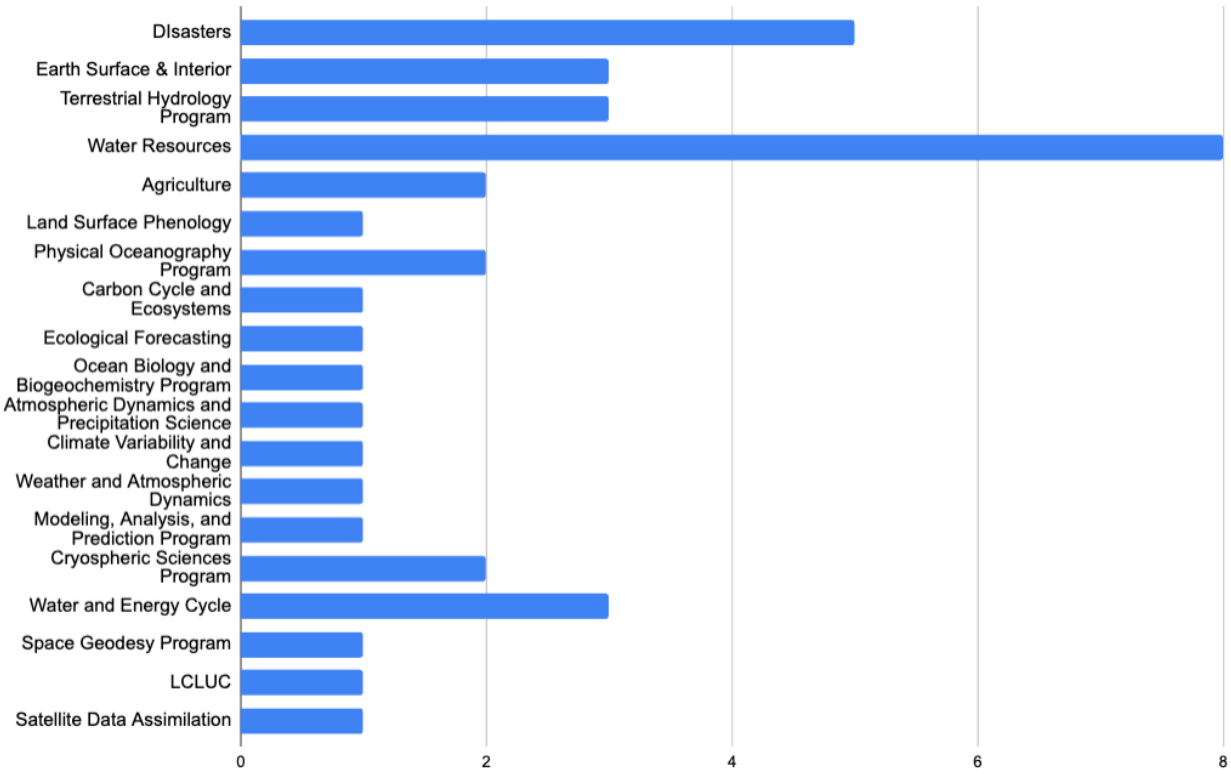

Figure 2. Evaluation research areas were varied, and some evaluations covered more than one research area.

The major programmatic findings from the Capella study are:

1. Evaluations teams had a difficulty staying within their data allocations – some rebalancing was required but the overall program quota was not breached
2. New acquisitions generally met requirements
3. The limited data archive hindered any meaningful evaluation of the utility of these data for temporal analyses.
4. No access to metadata without scene purchase was a limiting factor
5. Found a lack of transparency for data product algorithms and descriptions
6. Available data did not include low level product access desired by experts (e.g., no raw data)
7. The Capella system was responsive and reliable for standard products – radar "brightness" images

The PIs and their evaluation teams in principle had access to the Capella archive and the opportunity to task Capella's constellation, but finding relevant archived data was challenging. Some of the data used during this 1-year evaluation was from the archive, but most comprised new taskings. The key findings address the evaluation criteria of the CSDA Program below.

3.1 Data Access, Customer Support, and Metadata

Data Access

Data access provided by Capella Space for this evaluation was overall very good, but many PIs made recommendations on how Capella could improve data access going forward. Utility of the Capella Console for tasking and the archive varied by investigation, with some groups very satisfied with the availability and order responsiveness and others having more trouble identifying needed scenes due to lack of coverage over their areas of interest. For the most part each PI team received sufficient data to carry on their investigation.

One exception to data availability applied to the teams studying the cryosphere. At the beginning of the study there were two satellites in a sun-synchronous orbit reaching polar regions, but these two were among those removed from operation during the study period and were not replaced. This caused the PIs with study sites near the poles to make do with a limited amount of data and no tasking opportunities. These teams requested that Capella launch more satellites in polar orbits in the future.

It is also important to note that Capella does not formally support InSAR products. While some InSAR-quality repeat data exist, these cannot be identified easily in the archive as the metadata available on the Console does not include spatial and temporal baselines. Rather, those seeking to do InSAR analysis had to ask the engineering team to identify and deliver InSAR data outside of the Capella Console, resulting in only a handful of scenes. The PIs wishing to evaluate InSAR data worked extensively with Capella to attempt to identify acquisitions that could be used for InSAR applications, with limited success.

Metadata and Documentation

The Capella metadata included acquisition information, sensor calibration, and instrument characteristics with all orders. Metadata provided by Capella was deemed sufficient and thorough by many of the PIs. Several PIs noted that it would have been necessary for their research to have metadata about the perpendicular baselines and orbit tracks of the acquisition. PIs, particularly those doing InSAR research and applications would have benefited from these additional details and information when selecting data for analysis.

Capella provided the evaluation teams with documentation of the products, file formats, and metadata structure. Overall, the majority of the documents provided by Capella were very helpful, although some teams found that they were not comprehensive enough for detailed scientific analysis. In particular, orbit solutions would have been helpful prior to purchase to identify useful imagery. Similarly, the accuracy of the orbits provided in the extended metadata was not sufficiently accurate for some analyses.

User Support

During the evaluation, Capella provided very responsive and professional support to the CSDA Program PIs and evaluation teams. A large majority of the PIs had very positive comments regarding their interactions with Capella and their customer service representatives. Only a small minority of PIs claimed they did not have a positive experience in their interactions with the customer service team.

3.2 Data Utility for NASA Science

CSDA conducted a comprehensive evaluation of the Capella Space SAR data capabilities across multiple Earth science disciplines, including geohazards, cryosphere, ocean surfaces, agriculture, and coastal studies. The assessment examined various technical aspects such as data quality, spatial resolution, temporal coverage, and operational characteristics of the constellation. Depending on the needs of each science discipline and the variations among individual efforts, some system characteristics can be reported as positive for one discipline while they can have a negative impact for another science team. This review provides insights into both the potential and the limitations of Capella commercial SAR data for NASA's Earth science applications, highlighting areas where the system excels, and identifying critical gaps that need to be addressed for more effective scientific use.

<u>Geohazards and InSAR Analysis</u>
The evaluation teams that focused on InSAR applications found it difficult to participate in this evaluation. Evaluation teams were unable to task new acquisitions that guaranteed interferometric quality. However, Capella Space did provide several previously acquired image data stacks that were interferometrically viable for the PIs to evaluate. The evaluation teams found these time series useful for evaluating the data, although the PIs would have preferred to have access to orbit and baseline information prior to data order to select the preferred imagery, as well as the Level 0 data, in order to process the data to a higher quality for their applications.

The PIs with InSAR and hazard focused evaluation studies revealed mixed results for their applications. The data offers some notable advantages, including fine resolution capabilities that

enable lava flow identification with sufficient geolocation accuracy for certain types of studies. Limited rapid repeat coverage was available over volcanic sites. Several significant limitations were identified for this area of study. The lack of raw (Level 0) data access and missing metadata pose fundamental challenges for scientific applications of these data. The CPHD product documentation is lacking, and the unknown preprocessing step renders it unsuitable for InSAR applications. Archive coverage is a major concern, with 93% of active volcanoes lacking prior data coverage, typical of newer high-resolution small footprint constellations. The limitations on searching suitable archive data based on orbital baselines exist due to lack of metadata information exposed through the application programming interface (API) or the web-interface. Limited orbit control constrains InSAR capabilities, while inadequate geolocation accuracy prevents stacking applications. It must be stated that interferometric products were not commercially available at the time of this evaluation and all analysis was done on opportunistic and experimental data that was provided by the vendor for interested evaluators. These findings are included only in the report for completeness.

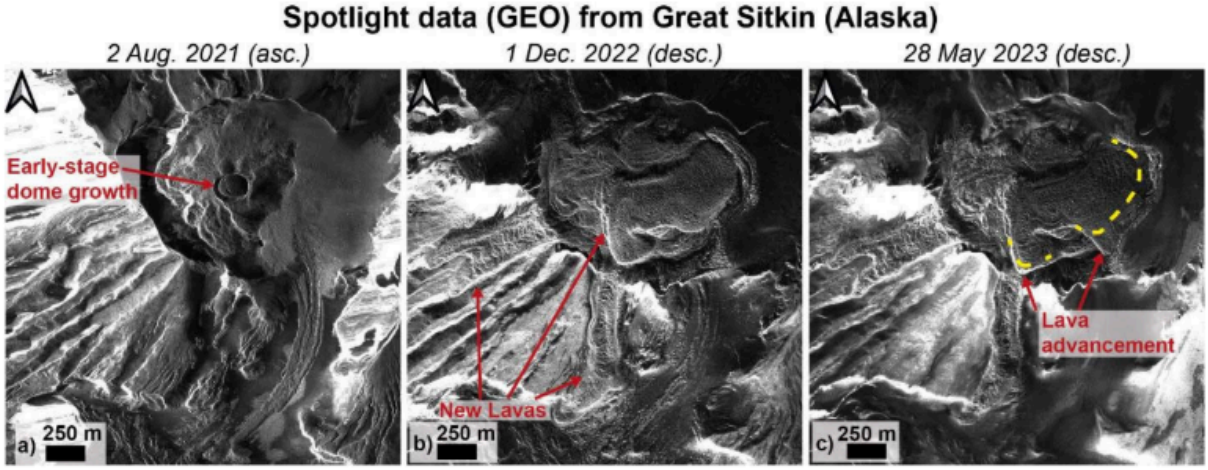

Figure 3. Capella spotlight data showing lava dome formation (a) and growth (b-c) at the Great Sitkin volcano (Aleutian Islands, USA). Dotted yellow line in panel c shows the extent of the dome in panel b and how the flow expanded.

Cryosphere Science

The main issue for the cryosphere teams was data availability following the demise of the polar-orbiting satellites. The loss of polar data limited or changed the evaluation plans of the cryospheric science teams. Despite this major issue, the assessment did reveal several notable strengths. Capella's API tasking system demonstrated strong performance with a 90% success rate, and the data provided fine resolution with geolocation accuracy sufficient for cryospheric studies. The availability of cloud-optimized geolocated imagery, and the ability to detect changes in surface roughness, were additional positive attributes. However, several critical limitations were identified. The archive data search functionality lacks key search parameters, and the absence of polar-orbiting satellites significantly impacted cryosphere studies that required new tasking. The system's temporal resolution was found to be limited to daily acquisitions during this evaluation, with little to no sub-daily repeat capabilities and generally few repeat observations. The cryosphere teams were interested in performing InSAR analyses, but Capella did not have commercial products suitable for interferometry. Like the teams investigating geohazards, the cryosphere

teams also found that the poor orbit control has rendered interferometry nearly impossible, and the geolocation accuracy is insufficient for data stacking applications.

Ocean Surface Properties

The successes in observation of ocean surface properties were mainly due to the ability to split spectrum processing of spotlight data to form temporal sequences on the order of a few seconds, and the classification of dynamic ocean features. Capella demonstrated effective tasking capabilities, long extended aperture dwell time for change detection, and superior spatial resolution compared to commonly available sensors. The ability to operate through cloud cover, which typically impedes optical data collection, proved valuable. Additionally, the system achieved approximately 5-meter geolocation accuracy and provided accurate and useful sea surface texture measurements. However, significant limitations were also identified. The CPHD product contained numerous errors resulting in artifacts in generated full-aperture imagery, making only Single Look Complex (SLC) data reliable for analysis. The constellation coverage excluded high latitude regions for sea-ice applications, and users faced challenges with inconsistent order status notifications and frequent cancellations. Future acquisition opportunities proved difficult to predict, and the system exhibited substantial antenna pointing and calibration errors.

Agriculture & Soil Moisture

The evaluation of agricultural and soil moisture applications revealed that the fine resolution of the Capella images permitted development of regression equations for soil moisture using VV data at small spatial scales that were particularly useful for assessing agricultural plots. Additionally, it also permitted tracking of fire scars that alter the landscape by delineating exact boundaries on the ground. The system demonstrated quick turnaround for data order and delivery times, clear visibility of backscatter changes during growing seasons, and superior spatial resolution compared to publicly available SAR systems. However, several challenges were also noted with the data, including poor georeferencing that complicated its use and comparison with other data sources, challenges with ordering through the Capella Console, and limitations to the ordering process that currently only allows single orders, with limited support for automated repeat acquisition tasking over the same area of interest.

Coastal Environment

Another group of PIs examined the utility of the data for studies of coastal properties and for shoreline tracking and identification. Several comparisons of ground unit classification and of identification of surficial material in the ocean, such as algal blooms, were quite successful. Several positive aspects were identified, including a responsive support team with clear documentation, effective urgent tasking capabilities, fine resolution, and sufficient geolocation for certain studies, as well as reliable day/night imaging functionality. However, multiple limitations were also noted. The system's coverage was restricted to small areas, and users encountered inconsistencies in API planning and parameter availability. While the tasking was flexible, the online user console presented a steep learning curve for users. The tasking and delivery of background images proved challenging, with only a 40% tasking success rate. Additional challenges included the need for repeat acquisition tasking capabilities, difficulty in obtaining incidence angle metadata, geolocation distortions, poor backscatter calibration, and inadequate revisit times. These limitations significantly impacted the system's overall utility for comprehensive coastal and water studies.

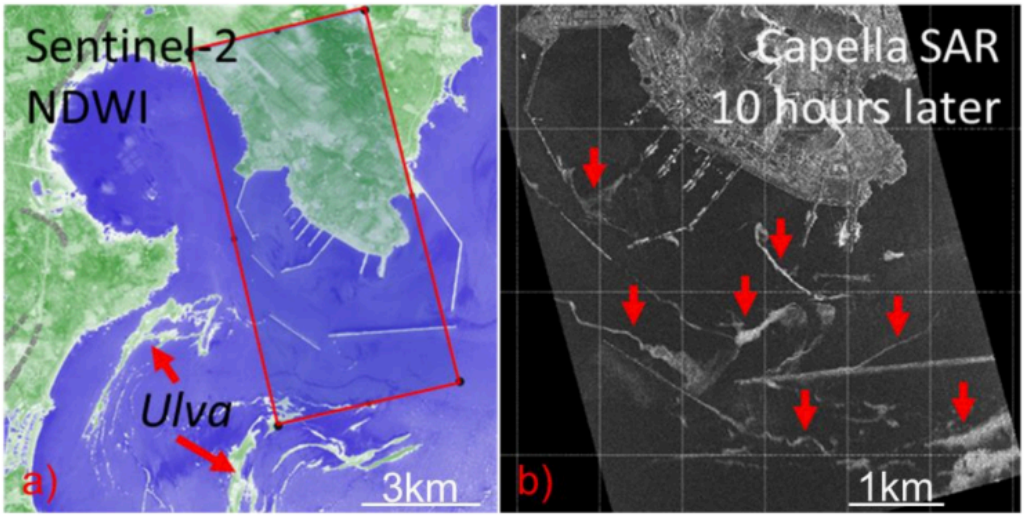

Figure 4. On the left, image (a) shows the Qingdao Naval base and nearshore, with *Ulva prolifera*, identified as green patches in the Sentinel-2 normalized difference water index (NDWI) image (06-25-2022, 02:58 UTC). On the right, image (b) is a Capella SAR VV sliding spotlight acquisition (06-25-2022, 12:35 UTC) shows detections of positive-contrast features. In the intervening 10-hour period, some of the floating algae moved within the harbor area (inside the breakwaters, identified as long linear features in the imagery).

Summary of NASA Data Utility

Across all science disciplines evaluated, several common themes emerged regarding the capabilities of Capella's SAR constellation. The system's fine spatial resolution consistently stood out as a significant advantage, enabling detailed observations from volcanic activity to agricultural plots and coastal features. However, fundamental limitations were identified across multiple disciplines, particularly regarding geolocation accuracy, spatial coverage constraints, and data acquisition challenges. The loss of polar-orbiting satellites, just before and also during the evaluation period, severely impacted both cryosphere and high-latitude studies, while poor orbit control affected interferometric applications across geohazard and cryosphere applications. While the system demonstrated strengths in rapid tasking and data delivery, a greater number of satellites in each Capella orbit (both polar and mid-inclination orbits) is essential for continuity in time series analysis. Users across disciplines encountered difficulties with the ordering interface, metadata accessibility, and multi-temporal acquisition capabilities. The evaluation revealed that while Capella's SAR data shows promise for specific applications within each discipline, significant technical and operational improvements are needed to better support NASA's diverse Earth science requirements. These improvements should focus on expanding spatial coverage, enhancing geolocation accuracy, improving orbit control, and streamlining the data acquisition process to better serve the broader scientific community.

3.3 Data Quality Assessment

The most common issue that was mentioned by most evaluation teams was the geolocation of the delivered products. This was especially prevalent when evaluation teams were using InSAR-ready products, as these need submeter level alignment. The magnitude of the geolocation errors varied amongst the evaluation teams from a few meters to 100s of meters, depending on how the evaluation team processed the data and the location of the scene. Lack of transparency for the

CPHD packaging algorithm and the general unavailability of raw data clearly compromised low level assessment of the system performance.

A very small number of evaluation teams documented small radiometric calibration issues, mainly in terms of variation in repeat measurements because true radar backscatter properties were not known in any of the regions studied.

For more details on the radiometric and geometric quality assessment, please refer to the CSDA Quality Assessment report on Capella Space. A summary of the results from that report is presented below in Figure 5.

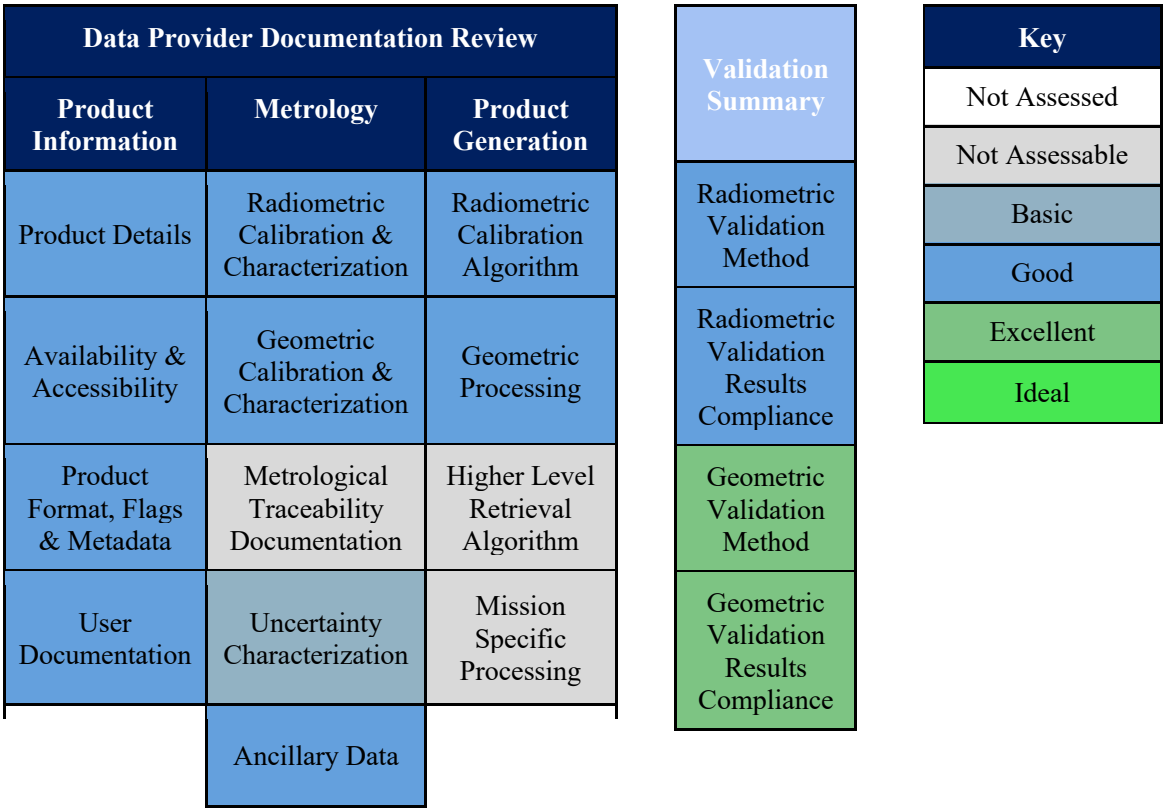

Figure 5. Summary Cal/Val Maturity Matrix from the Capella SAR Quality Assessment report.

4. Recommendations

The overall recommendation for Capella data following the one-year evaluation period was positive. A number of the NASA research and applications activities spanning multiple thematic areas were able to demonstrate a benefit of incorporating and utilizing fine resolution radar data, even if scene sizes are small. Research and application areas that reported reservations about using Capella data, especially those requiring specific repeat data for InSAR, recommended that future agreements between NASA and Capella look for a viable option to provide InSAR data and their

appropriate metadata. A large majority of evaluation teams also stressed that if the geolocation errors were reduced/fixed and/or improvements were made to accessing the archive and data ordering process, the strength of their recommendations would increase. The very high spatial resolution imagery provided by Capella Space and the ability for researchers to potentially task the constellation for their areas of interest would indeed complement and augment NASA's existing Earth Observation capabilities.

5. Conclusions

This evaluation determined that Capella Space data would complement NASA's existing Earth observation capabilities. The benefits of a resolution that is finer than NASA and ESA platforms by a factor of 10-50, although covering smaller areas, make the data suitable for local scale Earth science studies. The Capella system demonstrated effective tasking capabilities with quick response times for new acquisitions and included some repeat datasets for our evaluation, albeit limited in number. The Capella support team has proven responsive, and the platform effectively supports research requiring fine-resolution localized image products. Many areas for improvement remain, specifically, more transparency of data algorithms used to generate the data products (i.e. ATBD), and more detailed metadata is desired, especially regarding orbit tracks. The limitations of the Capella Console interface included restricted archive coverage, limited polar coverage (< 58°) due to loss of sun-synchronous satellites during the evaluation period, and small scene sizes that constrain applicability to many larger scale studies. To enhance future utility, improvements are needed in geolocation accuracy, product algorithm descriptions, and the availability of raw data (Level 0). A Level 0 option would make the acquired data more valuable to the NASA's radar science community. Overall, while Capella Space offers products that are complementary to existing NASA and ESA satellites, addressing these identified weaknesses would substantially improve its research applications and overall utility to the NASA's Earth science community.

Appendix A. Listing of Evaluation Research Projects

Project Title	PI & Institution
Geohazards and InSAR Analysis	
Assessing Capella Space Synthetic Aperture Radar Data for Global Volcanic Hazard Mitigation	**Matthew Pritchard**, Cornell University
Assessment of Capella Space Radar Constellation for Rapid Repeat, Fine Resolution InSAR Applications	**Howard Zebker**, Stanford University
Cryosphere Science	
Evaluation of Capella X-band SAR Data to Capture High Resolution Cryosphere Dynamics	**Scott Henderson**, University of Washington
Evaluation of Capella Space SAR Data as a Means to Advance Cryospheric Sciences	**Ute Herzfeld**, University of Colorado Boulder
Ocean Surface Properties	
On the capacity of Capella Space X-band SAR in Detecting Floating Matters	**Brian Barnes**, University of South Florida
Capella SAR Technical Evaluation	**Mark Sletten**, Naval Research Laboratory
Is Capella Space Ocean SAR Imagery Suitable for Maritime Air-Sea Coupling Applications?	**Justin Stopa**, University of Hawaii
Agriculture & Soil Moisture	
Evaluating the Sensitivity of Fine Spatial Resolution X-band SAR Time Series to the Phenology of Multiple Crops Using Capella Space Products	**Geoffrey Henebry**, Michigan State University
Assessment of Geometric and Radiometric Quality of the Capella Data for Soil Moisture and Waterbody Mapping	**Seung-bum Kim**, California Institute of Technology
Coastal Environment	
Evaluating the Capabilities of Capella Space Radar Imagery for High-Resolution Mapping of Surface Water Dynamics	**Sarah Cooley**, University of Oregon
Assessing the Radiometric and Interferometric performance of Capella Space SAR measurements for NASA Earth Science Research and Applications	**Emre Ertin**, Ohio State University
Evaluating Capella Space High-Resolution Data for Coastal Monitoring and Sustainable Water Management Practices	**Pietro Milillo**, University of Houston
Evaluation of Capella SAR Data for Mapping High-Tide Flooding Inundation Extent	**Tamlin Pavelsky**, University of North Carolina, Chapel Hill