A NEW VIEW FROM SPACE: MAKING TERRASAR-X DATA ACCESSIBLE TO THE CANADIAN RESEARCH COMMUNITY

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Abstract

This paper discusses work with TerraSAR-X data undertaken by the Maps, Data & Government Information Centre of the Trent University Library. It is divided into three sections: the first provides a brief description of TerraSAR-X satellite and imagery options, the second describes German-Canadian agreements for data access, and the third provides a brief overview of the Maps, Data & Government Information Centre's pilot project with imagery. This paper expands on information provided at the Association of Canadian Map Library and Archives (ACMLA) Carto2014 conference in Montreal in June 2014.

Introduction

In their roles as campus centres for spatial data and spatial technologies, libraries have partnered with a number of agencies to make their data and technologies widely available to Canadian universities for research and teaching. One recent and promising partnership, now under development, is that between the Canada Centre for Mapping and Earth Observation (CCMEO) of Natural Resources Canada, the German Aerospace Center Deutschen Zentrums für Luft- und Raumfahrt (DLR), Airbus Defence and Space, and Canadian universities. Its objective is to further current opportunities in place for accessing one type of satellite imagery: synthetic aperture radar (SAR) data produced by the TerraSAR-X satellite system. A particular focus of this initiative is on how libraries might play a role in facilitating the integration of these data sets into teaching curriculum. Discussions are underway to explore how libraries can facilitate access to data sets, expanding on existing DLR programs that a number of researchers have already made use of. This paper describes work underway at Trent University Library, in collaboration with other colleagues and agencies that explores the potential of this partnership. It, describes the TerraSAR-X satellite system and the imagery options that it provides, reviews background information regarding the German-Canadian agreement for TerraSAR-X imagery and options for obtaining imagery, and, finally, describes a pilot project now underway at Trent Library's Maps, Data & Government Information Centre (MaDGIC) that is examining how library technologies might be used to support the provision of these data.

Section One: Satellite Description[1]

TerraSAR-X (also referred to as TSX or TSX-1) is a German Earth-observation SAR satellite. It was launched on June 15, 2007, and it has been fully operational since January 7, 2008. The satellite is in a near-polar orbit, at an altitude of 514 kilometres and a revisit time of 11 days. In June 2010 TanDEM-X, a virtually identical satellite also owned and operated by the DLR, was launched and operates in close formation. Together they are acquiring data which will result in a variety of imagery and also permit the creation of a highly accurate global Digital Elevation Model.

The radar satellite technologies used by these satellites involve radar antenna which emit pulses of electromagnetic radiation in the microwave part of the spectrum, and then detect and record the reflection "echo" of the pulses from the object in its line of sight. Unlike optical sensors which rely on "passive" energy (such as the sun), a key advantage of "active" radar sensors is that they carry their own radiation source, and are therefore operational both day and night, during (most) inclement weather conditions. They can also penetrate cloud cover. As such they are well suited to a variety of applications such as disaster management, agriculture, forestry, marine study and security.

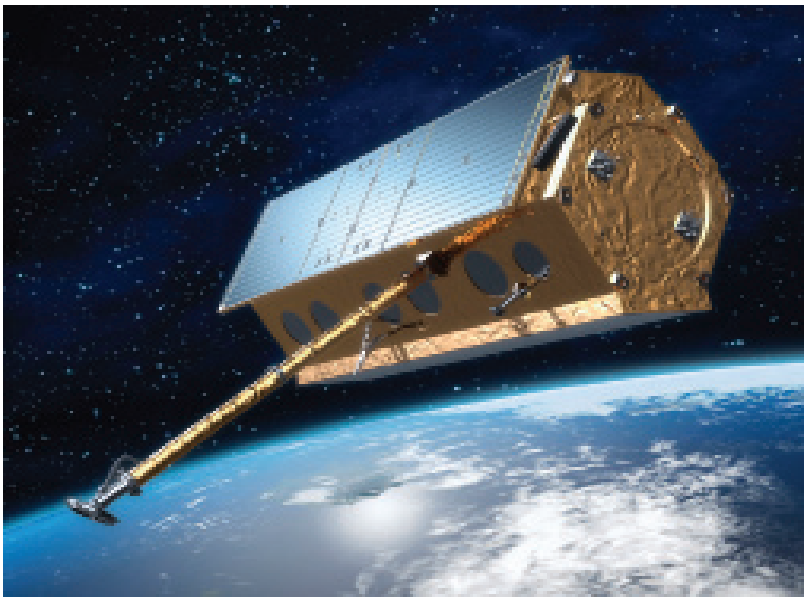


Fig. 1 TerraSAR-X Satellite

Source: German Aerospace Centre (DLR) web site. Taken down on 2 June 2014, from: http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10377/565_read-436/#gallery/350

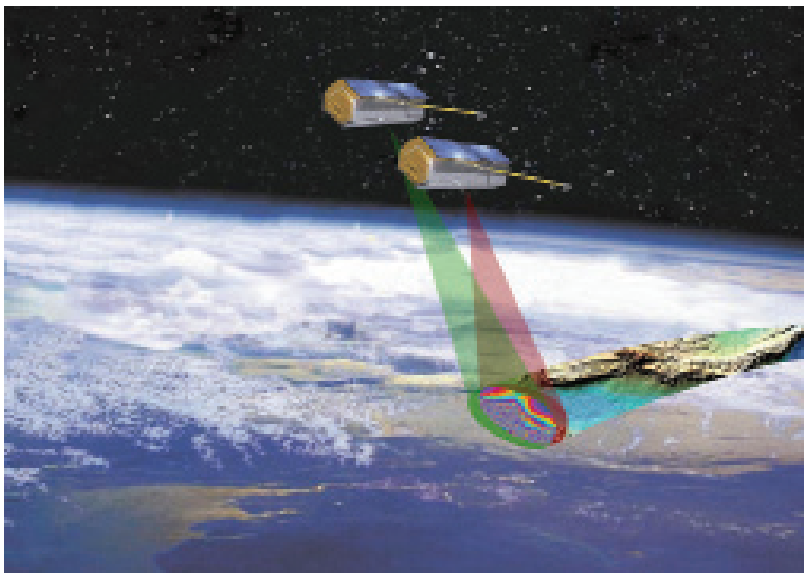


Fig. 2 TerraSAR-X and TanDEM-X: tandem formation

Source: Airbus Defence and Space. Taken down from German Aerospace (DLR) web site on 21 November 2014: http://www.dlr.de/eo/en/desktopdefault.aspx/tabid-5725/9296_read-15979/

The TerraSAR-X satellite carries a high frequency Synthetic Aperture Radar (SAR) X-band sensor which can be steered[2] and programmed to operate in different operational beam modes to obtain recordings of various strip widths, resolutions and polarizations.

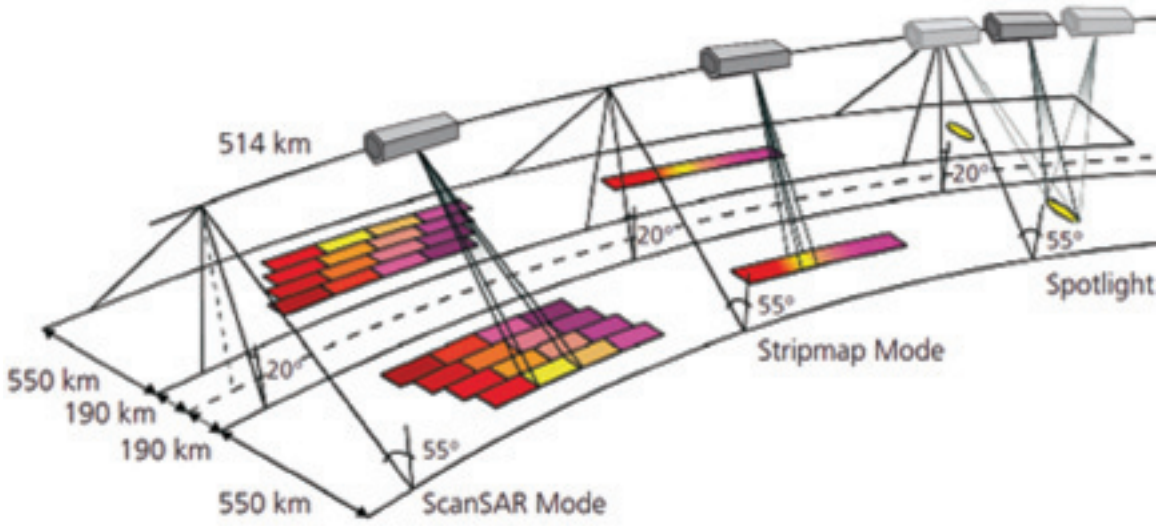
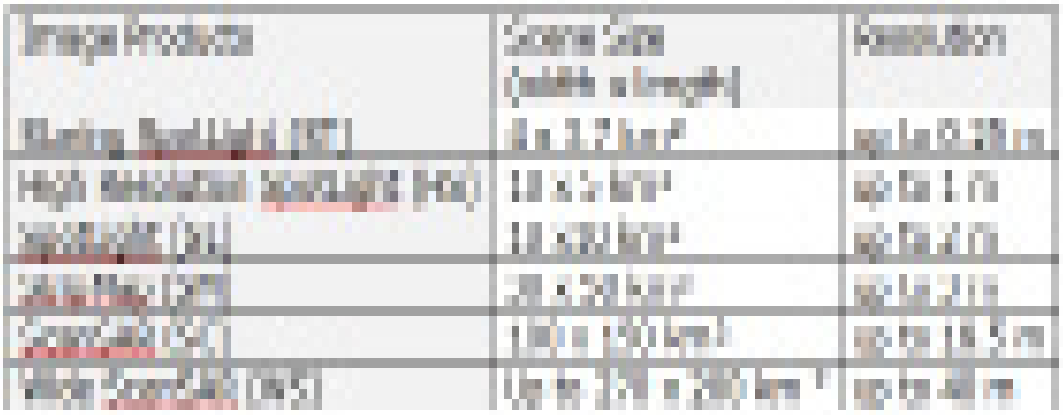


Fig.3 Scanning Modes of TerraSAR-X

Source: From German Aerospace (DLR) website description of TerraSAR-X Synthetic Aperture Radar (SAR) technologies. Taken down on 30 May 2014, from: http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10382/570_read-431/#gallery/356

Some key imaging modes:



Polarisation Mode:

Single(S) for all modes

Dual (D) for High Resolution SpotLight (HS), SpotLight (SL) and StripMap (SM)

Pass Direction:

Ascending (A) or Descending (D)

The following documents are recommended for further information on the TerraSAR-X satellite and available imagery products:

1. Airbus Defence & Space, TerraSAR-X Image Product Guide: Basic and Enhanced Radar Satellite Imagery, Issue 2.0 August 2014. Available from: http://www.geo-airbusds.com/files/pmedia/public/r459_9_201408_tsxx-itd-ma-0009_tsx-productguide_i2.00.pdf

2. DLR German Aerospace Centre TerraSAR-X The German Radar Eye in Space. TerraSAR-X_D-GB_July 20019. Available from: http://www.dlr.de/dlr/en/Portaldata/1/Resources/documents/TSX_brosch.pdf

Section Two: Opportunities for Academic Libraries and Researchers

This section provides some background on the status of the German-Canadian agreement for TerraSAR-X imagery: explaining who is involved in the negotiations, and how imagery for academic research can be obtained at this time.

Fig. 4 Participants

Source: Microsoft Office Power Point 2010, Clipart.

The TerraSAR-X project is supported by the BMBF (German Ministry of Education and Science) and managed and operated by the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR). In 2002 Airbus Defence & Space (at the time it was known as EADS Astrium) was awarded a contract to implement the TerraSAR satellite (TerraSAR-X) on the basis of a public-private partnership agreement. Airbus Defence & Space funded part of the implementation cost of the TerraSAR-X system, and successfully developed and tested the satellite system, receiving in exchange exclusive commercial rights for the data. The satellite is owned and operated by DLR, which also retains the scientific and educational data rights[3].

Canada has a long-standing interest in development and use of radar satellite technologies, including the Canadian RADARSAT-1 and RADARSAT-2 initiatives. In 2010 the Government of Canada established the Inuvik Satellite Station Facility (ISSF) in collaboration with a number of partners. Built above the Arctic Circle (a polar location improves reception) the ISSF land is owned by the Government of Canada and managed by the Canada Centre for Mapping and Earth Observation (CCMEO) of Natural Resources Canada. One of the antennas currently hosted by the ISSF belongs to the DLR.

Fig. 5 Inuvik Satellite Station Facility (ISSF)

Source: "Inuvik Satellite Station Facility. Terry Halifax Photography ©2011 downloaded on 3 June 2014, from: http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-facilities/ISSF/10953

Sensors on Canadian land are subject to the Remote Sensing Space Systems Act (S.C. 2005, c.45, assented 2005-11-25) which includes provisions for ensuring that raw data collected about a country be shared with that country (Section 4c)[4]. In the case of the specific Canadian agreement with the DLR it has been agreed that the CCMEO can access up to 400 scenes per year for each satellite that has had data received at the Inuvik Satellite Station Facility (ISSF). Faculty, librarians and graduate students can apply to obtain data for their research under this agreement following the process described below.

Academic research proposals, including requests for TerraSAR-X imagery, can be submitted to the DLR for evaluation through DLR's TerraSAR Science Service System. Forms and descriptions of different programs are provided at: http://sss.terrasar-x.dlr.de/. While some of the Announcements of Opportunity are time sensitive, applications can also be made at any time under the "General Proposal Submission" process. The DLR archive can be reviewed at any time through DLR's data portal EOWEB at http://centaurus.caf.dlr.de:8080/. Researchers wishing to obtain imagery may also wish to consult the archive maintained by Airbus Defence & Space (located at: http://terrasar-x-archive.infoterra.de/), to identify available imagery before defining their requests for new imagery to be tasked. Both new and archived imagery should be requested through this application process.

In addition to research proposals, the CCMEO, DLR, and Airbus Defence & Space are examining whether it will be possible to introduce TerraSAR-X data more broadly into teaching curriculum at Canadian universities and colleges. Dr. Gordon Deecker, Senior Advisor, Business, Planning and Development, has been consulting with some ACMLA members (including Larry Laliberté, University of Alberta, Simon Trottier from Université de Sherbrooke, and Barbara Znamirowski from Trent University) to see how we might move forward on this initiative, with a goal of implementing a "DLI type"[5] agreement.

A numbers of challenges exist to establishing a model that would allow libraries to dispense imagery to faculty and students for teaching or research under a collective agreement. Most notably, distribution of TerraSAR-X data has to comply with German Satellite Data Security Law (SatDSig) and the Canadian Remote Sensing Space Systems Act (RSSSA).

Canadian libraries wishing to learn more about getting data for a specific academic course should contact the author or Dr. Deecker from the CCMEO regarding options for data access and status of negotiations.[6] We are pleased that a process has been defined for considering individual research proposals from faculty, librarians and graduate students, and we will continue to explore avenues for introducing data through library agreements.

The remainder of this paper discusses Trent University Maps, Data & Government Information Centre's pilot initiative with SAR data.

Section 3: Trent Pilot Project

Application Process, Goals and Methodology

Between January and March 2014 Trent University Library completed the documentation process required for a Technical Evaluation of TerraSAR-X imagery. This included signing a Technical Evaluation License and providing a Certificate of Residence, Proof of ID, and photo ID.[7] Our project goals were to become familiar with the TerraSAR products, and to explore best practices for managing and introducing the data to faculty and students. We also wanted to evaluate how our existing technical framework and use of GIS web technologies could be adapted to support these goals.

In identifying an area of interest, it was suggested that we supply a shp extent file of our boundary comprising an area of not more than 6 to 8 km^2. A smaller area would keep overall file size reasonable for a test, and would ensure that the higher resolution imagery could be obtained in a single pass. The area we defined was Jackson Park, in Peterborough (Fig. 6), an area familiar to course instructors and many students.

Fig. 6: Study Boundary: Jackson Park, Peterborough, Ontario, Canada

Source: Ontario. Make a Topographic Map. Powered by Land Information Ontario.©Queen's Printer for Ontario, 2014 Downloaded on 23 November 2014, from: http://www.giscoeapp.lrc.gov.on.ca/web/mnr/gib/basedata/viewer/viewer.html?

Several factors make the Jackson Park area an appropriate site for this trial. This area includes several habitats: forests, stream, wetlands and open fields, as well as urban development, providing a basis for analysis of imagery of several land use types. The presence of diverse ecological habitats and hydrological

regimes provides an opportunity for analysis of, for example, habitat change over time and patterns of water flow and snow melt. The area is also facing pressures related to urban development, such as a proposed highway bridge across a natural area and a new suburban neighborhood planned adjacent to a significant wetland; images of these developments could provide a basis for analysis of their impacts.

We requested and received six images at different imaging modes of the same area.

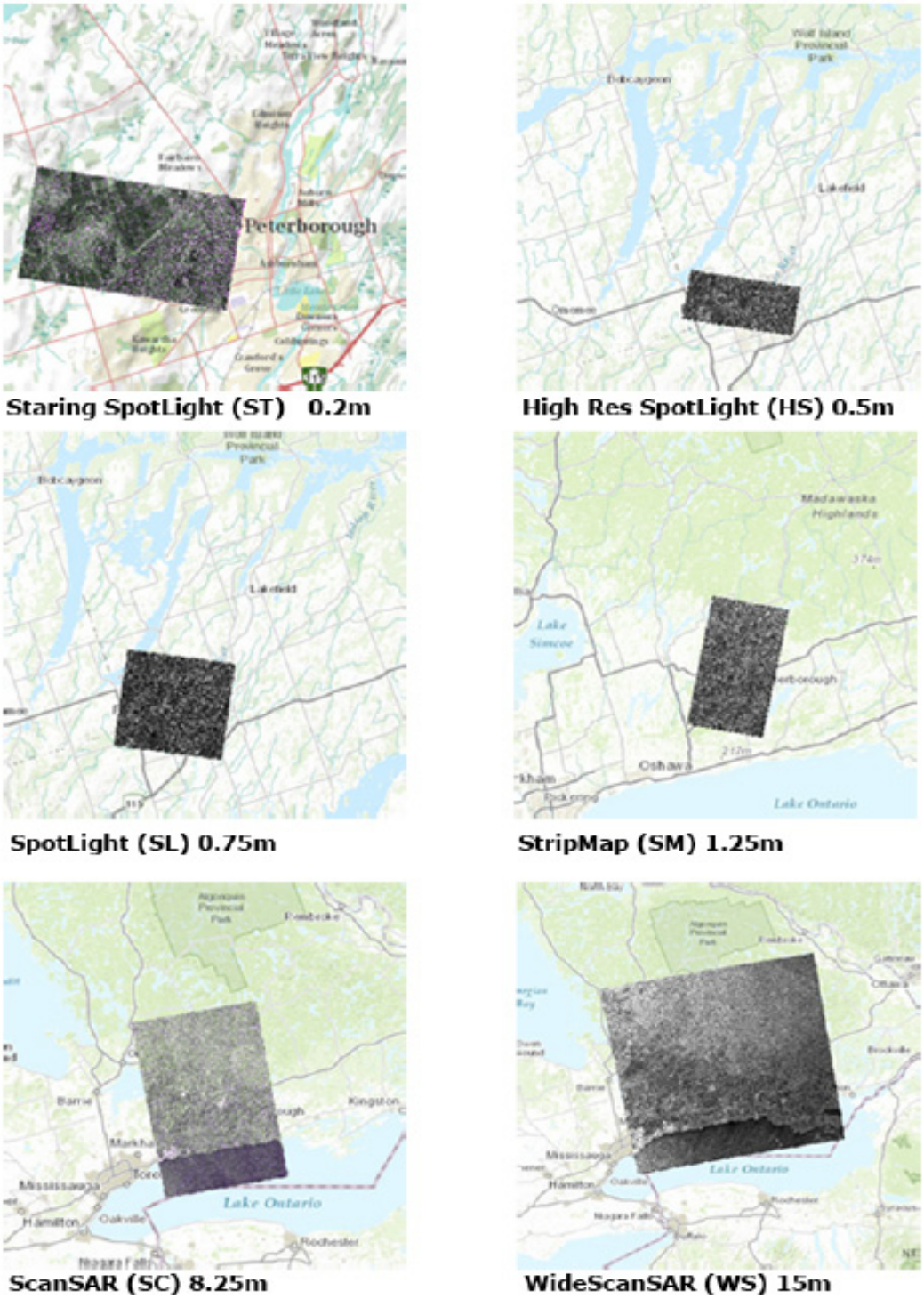


Fig. 7: Areas covered by imagery at six different imaging modes

Source: Imagery: TerraSAR-X imagery; Airbus Defence & Space and German Aerospace Center (DLR), Base Map: ESRI World Topographic Map Software: ESRI ArcGIS for Server 10.1

The download process was quick and intuitive, involving FTP transfer from Airbus Defence & Space.

Technical Procedures

We are publishing web services on a Windows 2008 server using ESRI ArcGIS for Server 10.1 and IIS. For the initial test, all development work was restricted to a Virtual Machine (VM) accessible only to staff of the Maps, Data & Government Information Centre.

Before publishing the data, several processing steps were completed. Initial processing of the data was done on a local machine using ESRI's ArcGIS for Desktop (ArcMap). This involved unbundling the six files we received (one for each imaging mode). We were impressed by the variety of products available for each mode, which included a high resolution TIFF file and composite 3-band images as well as extensive metadata.

Before moving the data to our server, we projected the imagery from the original coordinate system (UTM 17 N) to Web Mercator. Web Mercator is not necessarily the best for analytical uses, but it permits speedy reproduction on the web without intermediary caching. For the purposes of this test we have not created tile caches and are rendering images dynamically. This will give us more flexibility in future if we wish to adjust the service, or offer options for activating dynamic processes on the image. Using ArcGIS for Desktop the data was converted to raster pyramids (to increase rendering speed) and stored in file geodatabases. We created six file geodatabases to support the six web services we envisioned, one for each image mode containing five components: the original high resolution SAR image by itself, the composite 3-band image, and each of the single bands from the composite separately.

In addition to using ArcGIS for Server our GIS Developer has written a number of programs to support the web site, including work done in C# for compiled web applications working with IIS (for example, search results, list of services, secure paths that can be authorized), work done in python which interacts with ArcGIS for Server (for example, potentially, downloading of imagery) and work done in HTML 5, CSS and JavaScript for front end web site development (for example, drag and drop menus).

Figure 8 shows the structure of the ArcGIS for Server service directories and geodatabases.

Fig. 8: ArcGIS for Server Services Directory and Geodatabase structure

Source: Trent University Library ArcGIS for Server 10.1 TerraSAR-X directories

The services are called by a custom C# application, which is able read all component web services when the web site is opened, but only renders components visible when selected by the researcher. We did evaluate the feasibility of running separate services for each component of an image, but it was not considered essential for our purposes. We are managing the data deliberately this way to reduce the number of services required for display purposes within ArcGIS for Server. Although these methods require more programming work, there is less impact on server resources for publishing (including memory and CPU time).

A number of enhancements were added to the graphic interface including drag and drop menus, opacity options, and options for base maps.

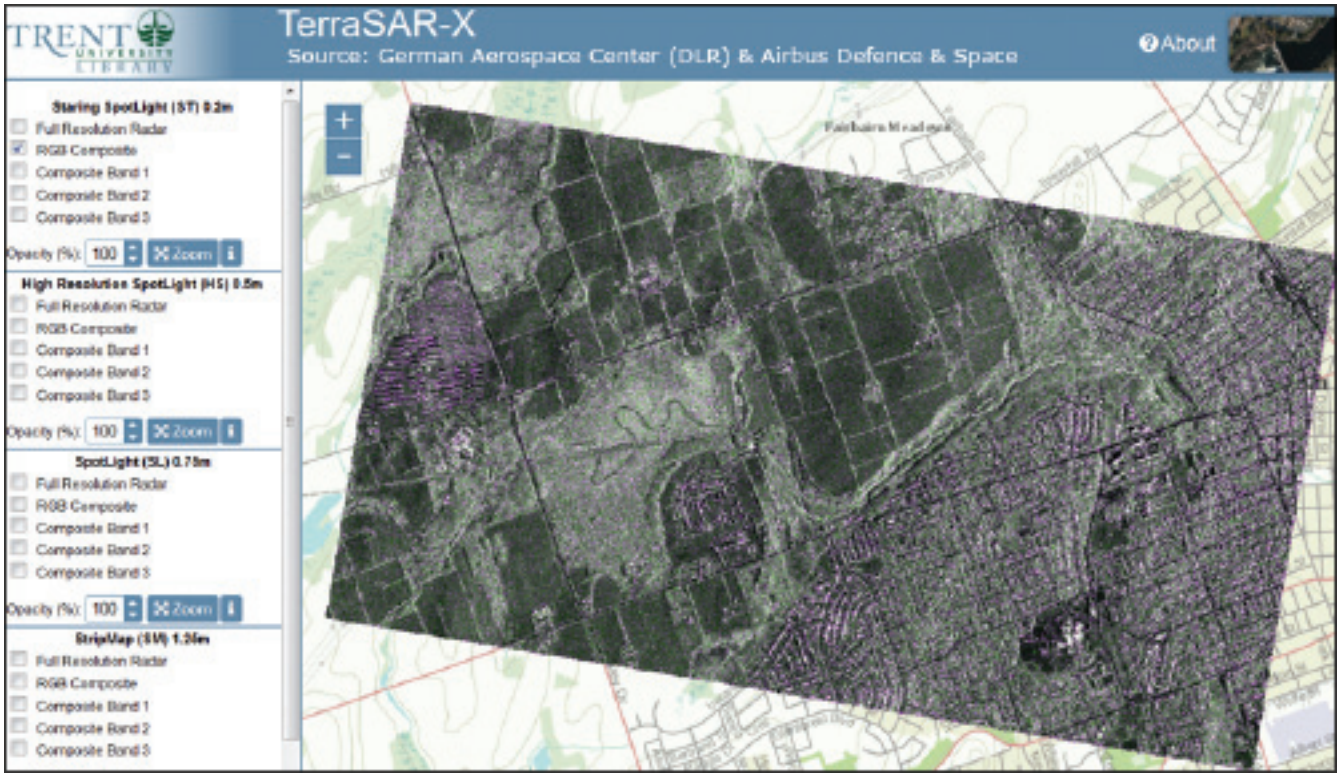


Fig. 9: Trent University Library Web Site for TerraSAR-X imagery showing Staring Spotlight image of Jackson Park

Source: Snapshot from Trent University Library Server, Data: Airbus Defence & Space and German Aerospace Center (DLR), TerraSAR-X Staring SpoLight (ST) 0.2m Composite, dims_op_oc_dfd2_372764075, 16 Februrary 2016, Production date: 3 March 2014 ©Airbus Defence and Space Base Map: Esri World Topographic Map, Software: Esri ArcGIS for Server 10.1

We received extensive metadata for each image, which came packaged as a large XML file, which then also linked to other XML files. At this time we have copied the file as one long xml page and made the information available from our web site through clicking on an "i" information button on the options menu. Eventually we would like to do further work on presentation of metadata, such as potentially writing a program to parse out essential fields from metadata and introducing different options for viewing the entire metadata file.

We are still evaluating options for download including authentication, but anticipate that the methodology would include something similar to what we currently use for aerial photography. This involves authenticating with Trent User ID and password through use of EZ Proxy and LDAP. During this process the researcher is also prompted to complete a brief online form which includes acceptance of license conditions. For download, images would be offered following our standard practice of delivering products in their original coordinate system, calling the image using a script (most likely python). We would also like to experiment with implementation of some of the analytical features available within ArcGIS for Server, such as, for example, applying high-pass or low-pass filters.

Conclusion and Acknowledgements:

Web GIS development work for this project was completed by Mike Kyffin, GIS Programmer and Developer, Trent Library Maps, Data & Government Information Centre.

Trent University Library is extremely grateful for the opportunity to participate in the Technical Evaluation of TerraSAR-X imagery. We wish to thank all persons and institutions involved in providing us with access to TerraSAR-X imagery, including Gordon Deecker, CCMEO, Alexander Kaptein, Airbus Defence & Space, Marchus Jochum, Airbus Defence & Space and Achim Roth, DLR. We look forward to making continued progress on a model library partnership agreement for all Canadian university libraries, and to further introducing TerraSAR-X imagery to our university communities and academic programs.

All inaccuracies or omissions within this article are the responsibility of the author.

[1]Information for Section 1 of this paper has been taken from:

1. Airbus Defence & Space, TerraSAR-X image Product Guide: Basic and Enhanced Radar Satellite Imagery, Issue 2.0 August 2014. Available from: http://www.geo-airbusds.com/files/pmedia/public/r459_9_201408_tsxx-itd-ma-0009_tsx-productguide_i2.00.pdf

2. DLR German Aerospace Centre TerraSAR-X The German Radar Eye in Space. TerraSAR-X_D-GB_July 20019. Available from: http://www.dlr.de/dlr/en/Portaldata/1/Resources/documents/TSX_brosch.pdf

3. eoPortal Directory, TSX (TerraSAR-X) Mission https://directory.eoportal.org/web/eoportal/satellite-missions/t/terrasar-x. Credit note on web site: "The information compiled and edited in this article was provided by Herbert J. Kramer from his documentation of:"Observation of the Earth and Its Environment: Survey of Missions and Sensors" (Springer Verlag) as well as many other sources after the publication of the 4th edition in 2002. - Comments and corrections to this article are always welcome for further updates (herb.kramer@gmx.net)" Available from: https://directory.eoportal.org/web/eoportal/satellite-missions/t/terrasar-x

[2]The DLR web sites expands on this key advantage as follows: "The radar beam can be electronically tilted within a range of 20 to 60 degrees perpendicular to the flight direction, without having to move the satellite itself. This has an obvious advantage: it allows the radar to zoom in on many more ground targets from the satellite's orbit than would be possible using a 'non-steerable' radar." http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10377/565_read-436/#/gallery/350, accessed on: November 8, 2014

[3]EO Sharing Earth Observations Resources, https://directory.eoportal.org/web/eoportal/satellite-missions/t/terrasar-x#footback109%29 and TerraSAR-X The German Radar Eye in Space, http://www.dlr.de/dlr/en/Portaldata/1/Resources/documents/TSX_brosch.pdf

[4] "(c) that raw data and remote sensing products from the system about the territory of any country — but not including data or products that have been enhanced or to which some value has been added — be made available to the government of that country within a reasonable time, on reasonable terms and for so long as the data or products have not been disposed of, but subject to any licence conditions under subsection (6) or (7) applicable to their communication or provision" From: Remote Sensing Space Systems Ace S.C. 2005, c.45 Assented to 2005-11-25

[5] Agreement modelled after the Data Liberation Initiative (DLI) held between Canadian universities and Statistics Canada.

[6]Barbara Znamirowski, Head, Maps, Data & Government Information Centre, Trent University Library: bznamirowski@trentu.ca ; Dr. Gordon Deecker, Senior Advisor, Canada Centre for Earth Observation, Canada Centre for Mapping and Earth Observation, Earth Sciences Sector, Natural Resources Canada: Gordon.Deecker@NRCan-RNCan.gc.ca

[7] The Certificate of Residence is an official document available from Canada Revenue Agency and required for European Union Tax Law; Proof of ID is an official letter confirming institutional identity and affiliation of researcher, photo ID must including citizenship information. It should be noted that research applications and technical evaluation applications vary in what forms are required and may not require all forms listed in this article. Applicants should verify requirements before applying.

Bibliography

Web Sites:

Airbus Defence & Space Archive, "TerraSAR-X Archive" http://terrasar-x-archive.infoterra.de/

Airbus Defence & Space, "TerraSAR-X Documentation" http://www.geo-airbusds.com/en/228-terrasar-x-technical-documents

DLR German Aerospace Center Web Site and brochures on TerraSAR-X http://www.dlr.de/dlr/en/desktopdefault.aspx/tabid-10377/565_read-436/#/gallery/350

DLR TerraSAR Science Service System http://sss.terrasar-x.dlr.de/

EO Sharing Earth Observation Resources eoPortalDirectory, https://directory.eoportal.org/web/eoportal/satellite-missions/t/terrasar-x

Natural Resources Canada Inuvik Satellite Station Facility http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-facilities/ISSF/10953

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Helko Breit, Thomas Fritz, Ulrich Balss, Marie Lachaise, Andreas Niedermeier, and Martin Vonavka, T*erraSAR-X SAR Processing and Products*, IEEE Transaction On Geoscience And Remote Sensing, VOL. 48, NO. 2, February 2010,727-740.

Jürgen Janoth, Steffen Gantert, Thomas Schrage, Alexander Kaptein, TerraSAR Next Generation – Mission Capabilities, Geoscience and Remote Sensing Symposium (IGARSS), 2013 IEEE International, 2297 - 2300.

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