Enhanced Very-High Resolution (EVHR) Products for NASA's Earth Science Investigators

Short project title: EVHR Products

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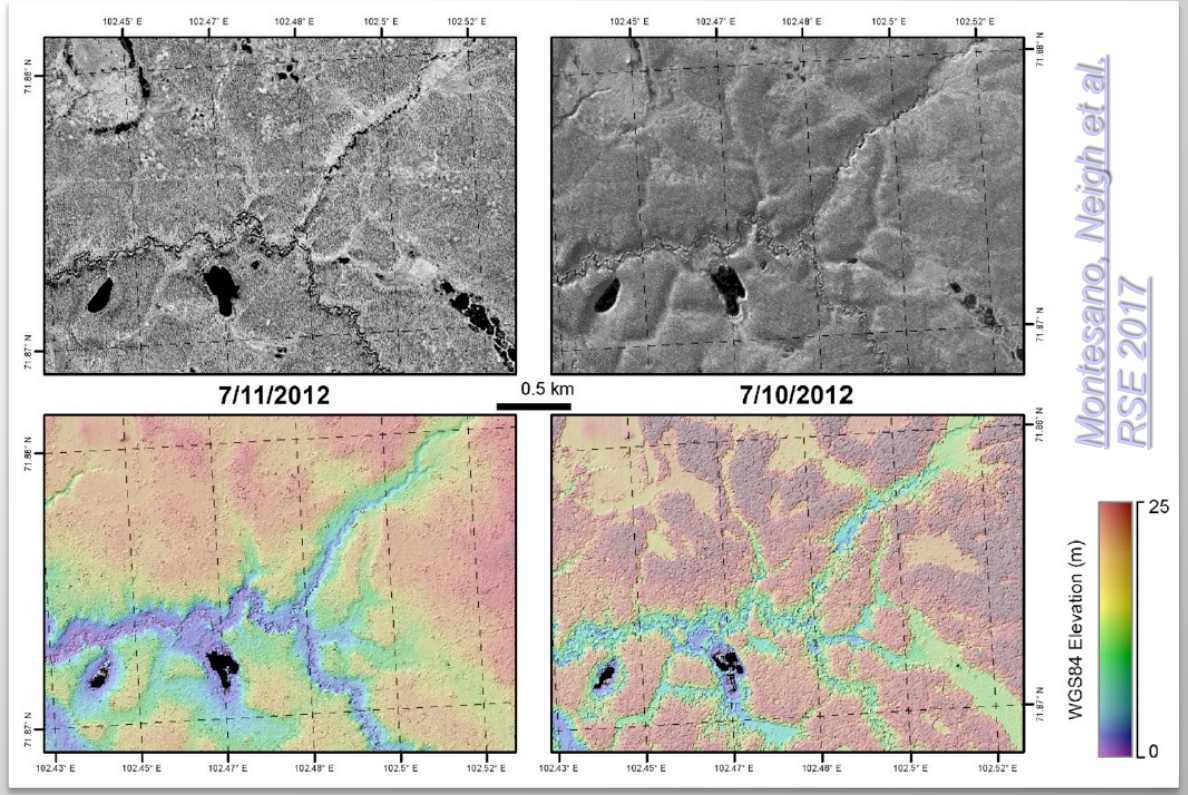


Panchromatic WV imagery with corresponding color-day apart shaded relief DSMs of the same location from stereopair acquisitions taken 1 with different sun elevation angles. ©DigitalGlobe NextView 2014

NASA ESTF 2019 NNH16ZDA001N-AIST 16-AIST16-0105

Outline

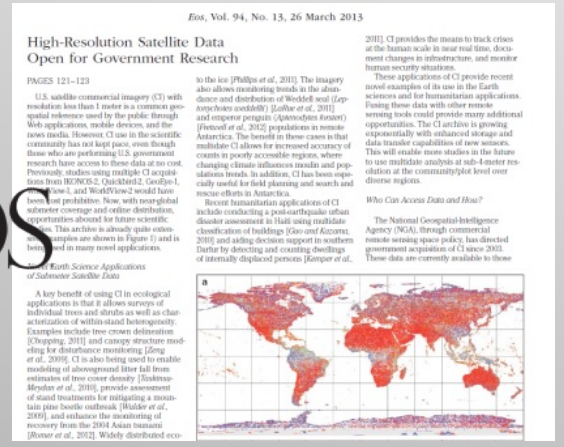
1) **Overview of the Enhanced Very-High Resolution (EVHR) products project**
   - Current status of access to DigitalGlobe data “NGA Nextview/NASA Databuy”
   - Scientist needs for commercial sub-meter data products
   - Science products derived from the API
   - Project status

2) **Examples of how derived products are used in Earth Science (brief literature review)**
   - Terrestrial ecology
   - Cryospheric sciences
   - Hydrology
   - Training data for thematic mapping classification algorithms
   - Validation/site characterization

Background - Why is an API needed?

Commercial Data Status

1. The volume of commercial sub-meter remotely sensed data is growing at rates exceeding petabytes per year and the costs for data storage systems and computing have both dropped exponentially.
2. US federal contracts and licensing agreements with DigitalGlobe has opened the door for “Big Data” processing to characterize land surface phenomena in HEC environments yet integration into NASA Earth Science has been slow (Neigh *et al.* 2013).


Eos, Vol. 94, No. 13, 26 March 2013

High-Resolution Satellite Data Open for Government Research

PAGES 121–123

U.S. satellite commercial imagery (CI) with resolution less than 1 meter is a common geospatial reference used by the public through Web applications, mobile devices, and the news media. However, CI use in the scientific community has not kept pace, even though those who are performing U.S. government research have access to these data at no cost. Previously, studies using multiple CI acquisitions from IKONOS-2, QuickBird-2, GeoEye-1, WorldView-1, and WorldView-2 would have been cost prohibitive. Now, with near-global submeter coverage and online distribution, opportunities abound for future scientific use. This archive is already quite extensive; examples are shown in Figure 1) and is being used in many novel applications.

Earth Science Applications of Submeter Satellite Data

A key benefit of using CI in ecological applications is that it allows surveys of individual trees and shrubs as well as characterization of within-stand heterogeneity. Examples include tree crown delineation [*Chopping*, 2011] and canopy structure modeling for disturbance monitoring [*Zeng et al.*, 2009]. CI is also being used to enable modeling of aboveground litter fall from estimates of tree cover density [*Tuominen-Meyden et al.*, 2010], provide assessment of stand treatments for mitigating a mountain pine beetle outbreak [*Wulder et al.*, 2009], and enhance the monitoring of recovery from the 2004 Asian tsunami [*Rumer et al.*, 2012]. Widely distributed ecotone ice [*Phillips et al.*, 2011]. The imagery also allows monitoring trends in the abundance and distribution of Weddell seal (*Leptonychotes weddellii*) [*Lathe et al.*, 2011] and emperor penguin (*Aptenodytes forsteri*) [*Fretwell et al.*, 2012] populations in remote Antarctica. The benefit in these cases is that multidate CI allows for increased accuracy of counts in poorly accessible regions, where changing climate influences moulin and populations trends. In addition, CI has been especially useful for field planning and search and rescue efforts in Antarctica.

Recent humanitarian applications of CI include conducting a post-earthquake urban disaster assessment in Haiti using multidate classification of buildings [*Gao and Karamo*, 2010] and aiding decision support in southern Darfur by detecting and counting dwellings of internally displaced persons [*Kemper et al.*, 2011]. CI provides the means to track crises at the human scale in near real time, document changes in infrastructure, and monitor human security situations.

These applications of CI provide recent novel examples of its use in the Earth sciences and for humanitarian applications. Fusing these data with other remote sensing tools could provide many additional opportunities. The CI archive is growing exponentially with enhanced storage and data transfer capabilities of new sensors. This will enable more studies in the future to use multidate analysis at sub-4-meter resolution at the community/plot level over diverse regions.

Who Can Access Data and How?

The National Geospatial-Intelligence Agency (NGA), through commercial remote sensing space policy, has directed government acquisition of CI since 2003. These data are currently available to those

a

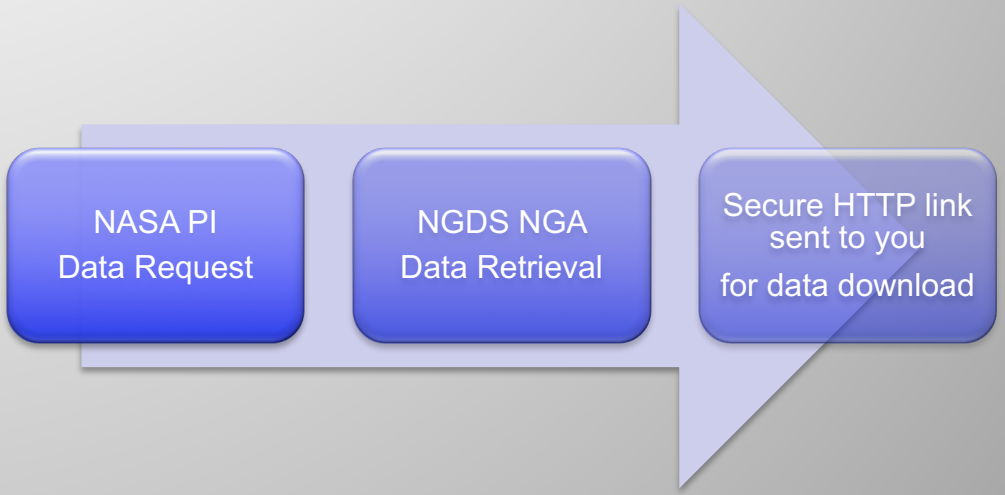
Neigh et al. 2013 EOS

Data are difficult to use by Earth scientists for 3 main reasons:

1. most of the very high-resolution (VHR) data received at NASA-GSFC are not in a standard, GIS-ready format, they come in Department of Defense (DOD) National Imagery Transit Format (NITF);
2. the raw data have poor horizontal and vertical co-registration; and
3. once ortho GeoTiffs are produced the data can have large file sizes (~5 Gigabytes for an individual image at 0.3 m to 30+ Gigabytes for a strip of those images) and require HEC environments to process and analyze many images in an efficient manner.

Access has been provided via NGA to archived DigitalGlobe imagery for use in NASA-funded research

- The National Geospatial-Intelligence Agency's (NGA's) extensive archive of commercial satellite data are available federally-funded users free of direct cost.
- We manage data acquisition for these users, many of whom are university affiliates without access to interfaces such as NGDS.
- Users register on our site, we verify NASA grant information for non-NASA users, provide license information and a data use agreement. Users are provided passwords that allow for data request submission, which we fill once signed DUAs are provided.
- Currently: 300+ registered users, over 8 years we have fielded > 400 user requests that have resulted in > 40 publications.



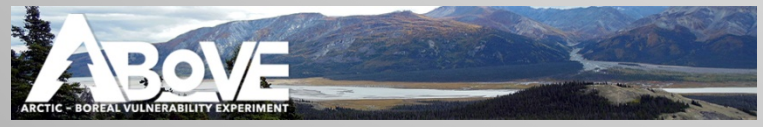
Background /Abstract Cont.

From our 8 years of experience delivering these data to NASA funded PI's, a bottleneck exists that impedes two common uses of these data:

1) Individual scenes for evaluation and validation of coarser resolution NASA EO products; and

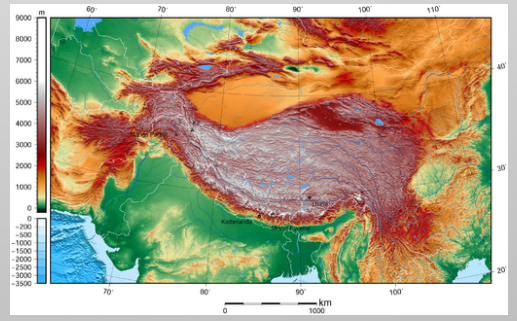
2) Analyses of VHR scenes to quantify environmental phenomena with object-based classification or 3D-reconstruction from one of many individual VHR scenes.

The target audience is broadly the community of NASA-funded Earth scientists, specifically scientists funded through ABoVE, HiMAT, and registered users of cad4nasa.gsfc.nasa.gov. Access to the VHR data is limited to NASA-funded researchers so we are targeting the ABoVE and HiMAT communities that are already users of the ADAPT system. Initial support for NASA Commerical Databuy PI's.



https://above.nasa.gov/

http://cad4nasa.gsfc.nasa.gov



himat.org

https://www.nccs.nasa.gov/services/adapt

DigitalGlobe Data Licensing and Copyrights

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- Temporary Licensed Users :
  - State Governments
  - Local Governments
  - Foreign Governments and inter-governmental organizations
  - NGO's and other non-profit organizations

All high-resolution commercial satellite imagery purchased by NGA is NextView licensed.
USG may provide the imagery to the above organizations when collaborating on an official purpose.

More information available here: https://cad4nasa.gsfc.nasa.gov/images/NGA-NextView-License.png

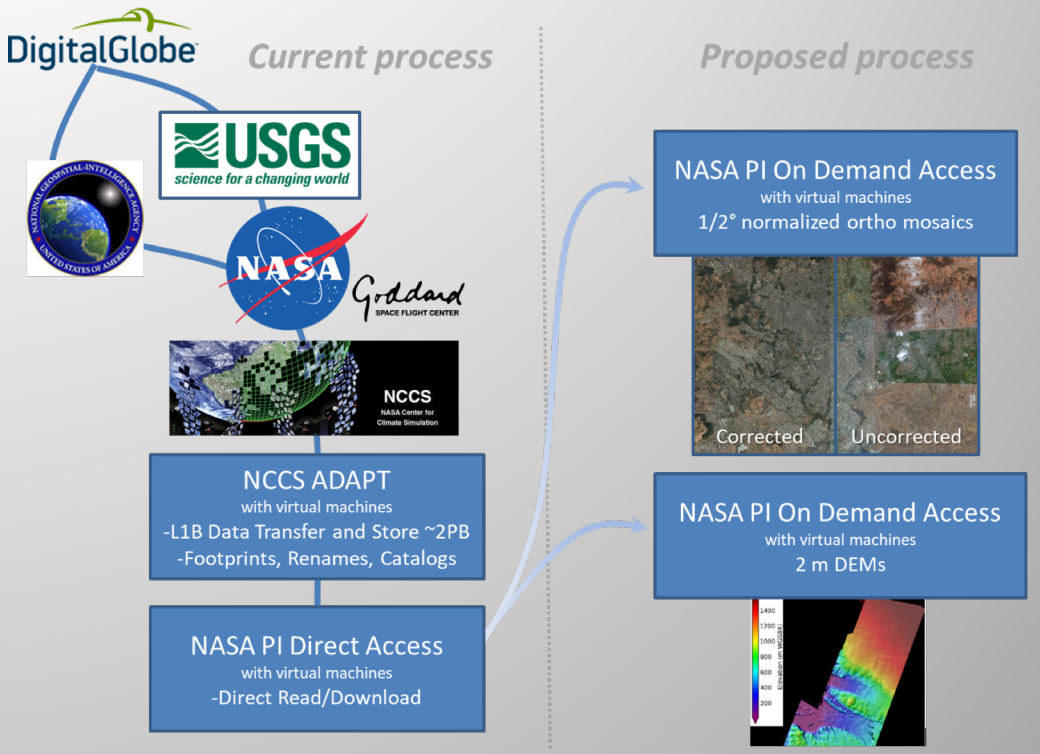
Objectives

Our work seeks to provide tools as an Application Program Interface (API) for mass processing spatially contiguous and temporally consistent archived NASA-GSFC DG VHR data that can only efficiently be performed on NASA HEC resources due to DG-NGA licensing limitations and computational requirements.

Our objectives are to:

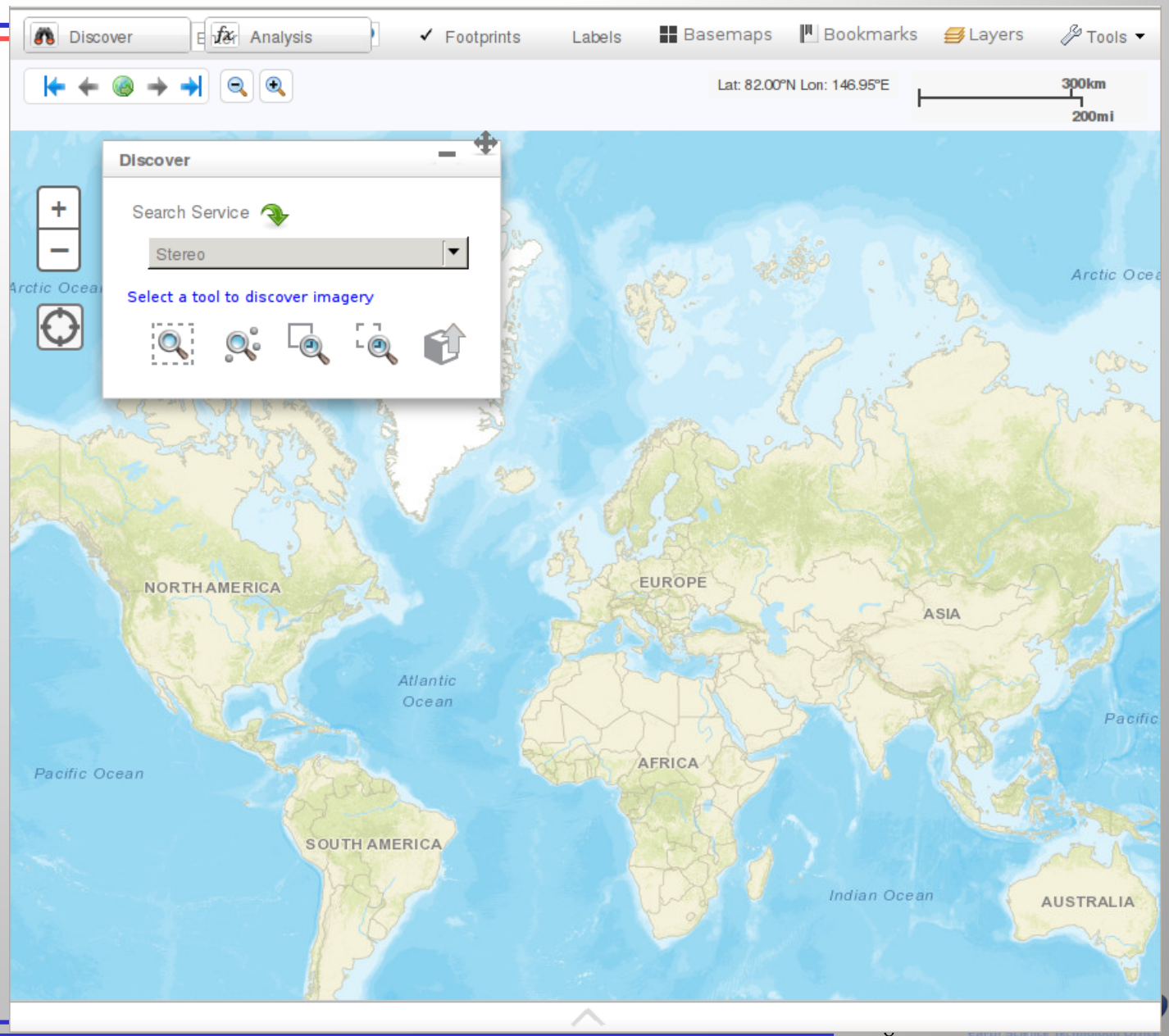
1. **Improve VHR data querying:** using databases and ArcGIS mosaic datasets within NASA-GSFC's ADAPT global archive of DG VHR imagery;
2. **Produce on demand VHR regional mosaics:** automating estimates of surface reflectance, ortho-rectifiying and normalizing 1 m mosaics for pan and 2 m for multi-spectral; and
3. **Produce on demand 2 m posting DEMs:** leveraging HEC processing and open source NASA-Ames software.

VHR data flow within the GSFC NCCS ADAPT HEC



Data Discovery- Automated Database

- Querying from a firefox browser on ADAPT:
  - Spatial search on individual image services
  - Preview returned images; filter on attributes.
  - Create selection, and export to CSV or shapefile
  - Query results can be sent to the API



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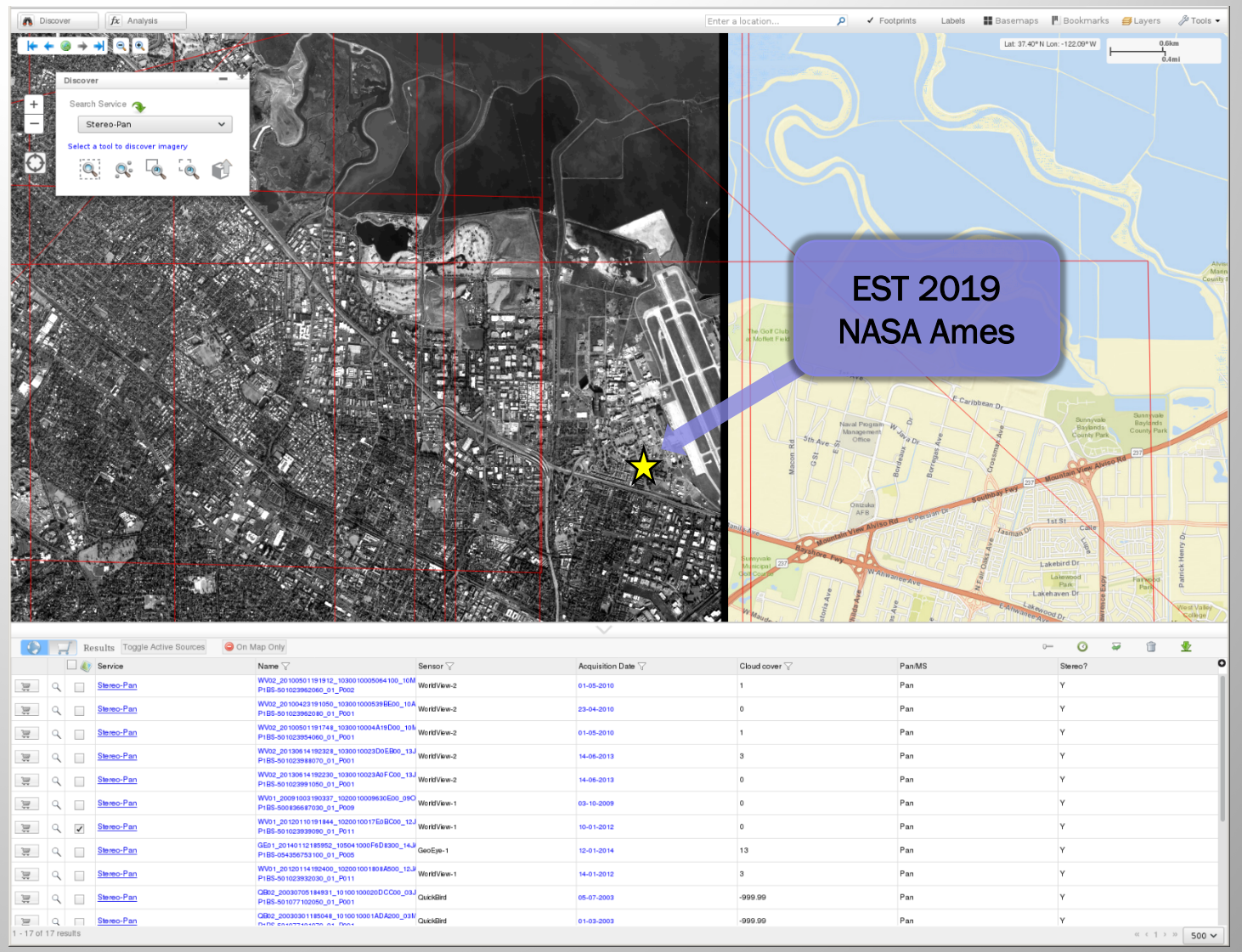
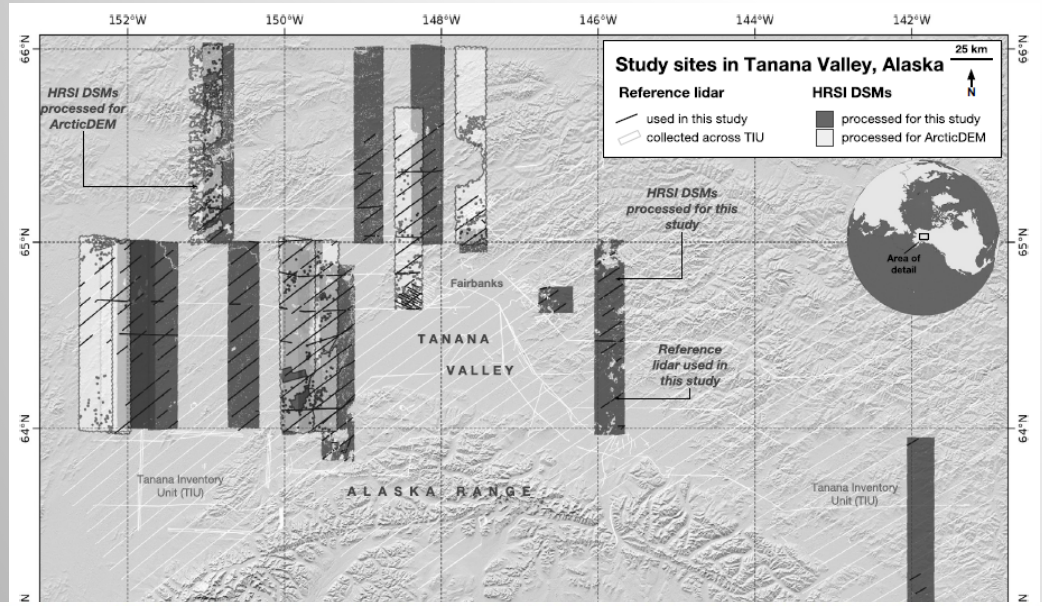


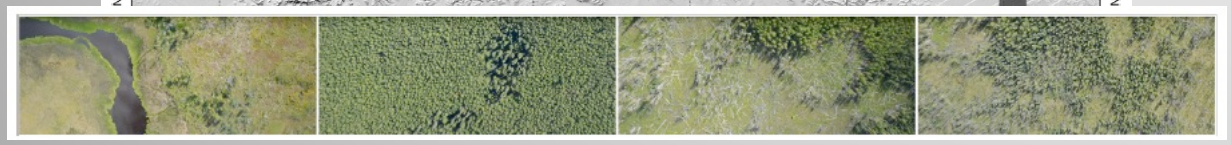
Reduced Resolution Mosaics

A WorldView-2 scene at full resolution (left) and reduced resolution (right)

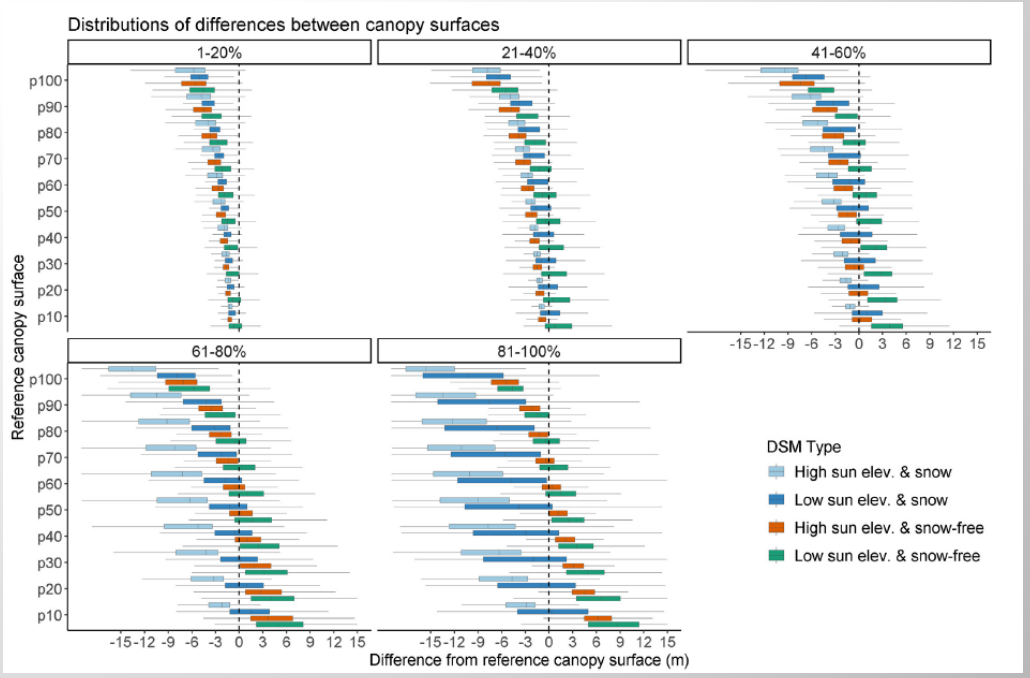
- Reduced resolution mosaics are used for previewing imagery in the data discovery tool
  - Testing indicates that switching from full-resolution to reduced resolution image previews improves drawing speed by 15 to 30 x
  - The global ADAPT archive of WorldView Multispectral data was downsampled to 10 m resolution
  - Processed over 1.2 million images, more than 450 TB reduced to 9 TB

DEM Process: standardized & optimized in HEC



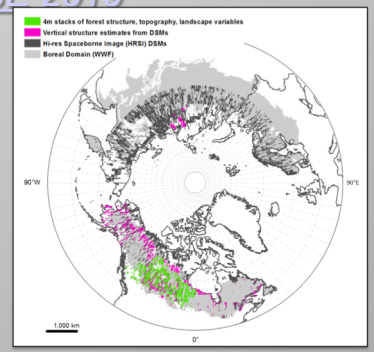


(Above) Study sites in the Tanana Valley, Alaska where reference lidar provided reference measurements of horizontal and vertical forest structure for coincident strips of DSMs. Below, aerial images highlight the diversity of forest structure patterns between sites.



Boxplots show the distributions of differences between DSMs and reference canopy surfaces for each DSM type across the 5 canopy cover intervals.

Montesano, Neigh et al. RSE 2019



Standardized the DEM processing of the image pairs returned from data queries:

- Incorporated lessons learned from **7,000+** DEMs processed using **14,000+** image strip pairs.
- Using tested parameters to maximize efficiency.

DEM Workflow: cont.
linking scientists with developers

Optimize the workflow on the NCCS **ADAPT** linux cluster **(Co-I Dan Duffy)**

- facilitate on-demand processing of imagery for study sites
- increase processing speed & efficiency, maximizing the use of HEC

The workflow will benefit from interaction between scientists & developers

- To guide on-going software updates
- To inform software functionality based on science objectives.

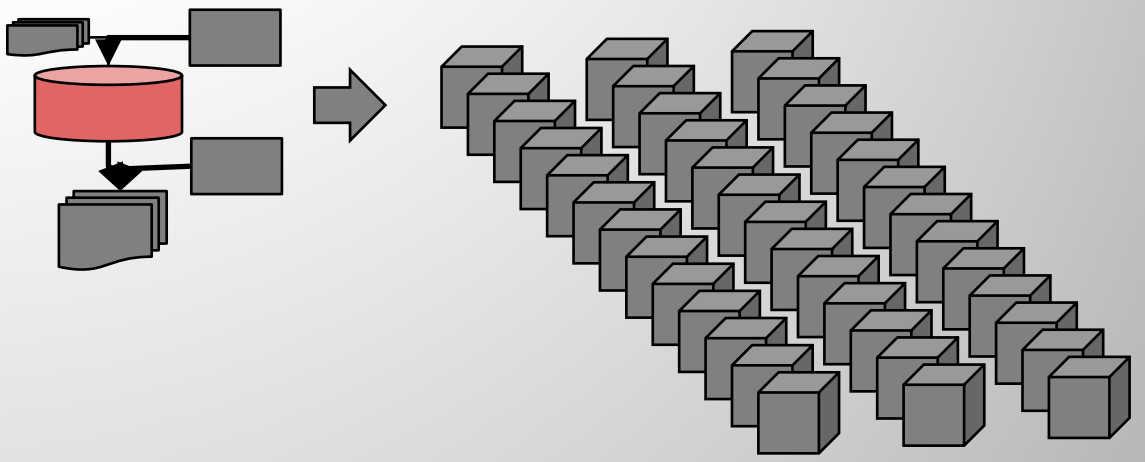
The NASA Ames Stereo Pipeline (**Co-I Oleg Alexandrov**)

- stereogrammetry routines for processing DigitalGlobe image pairs

Python & bash scripts (**Co-I David Shean**)

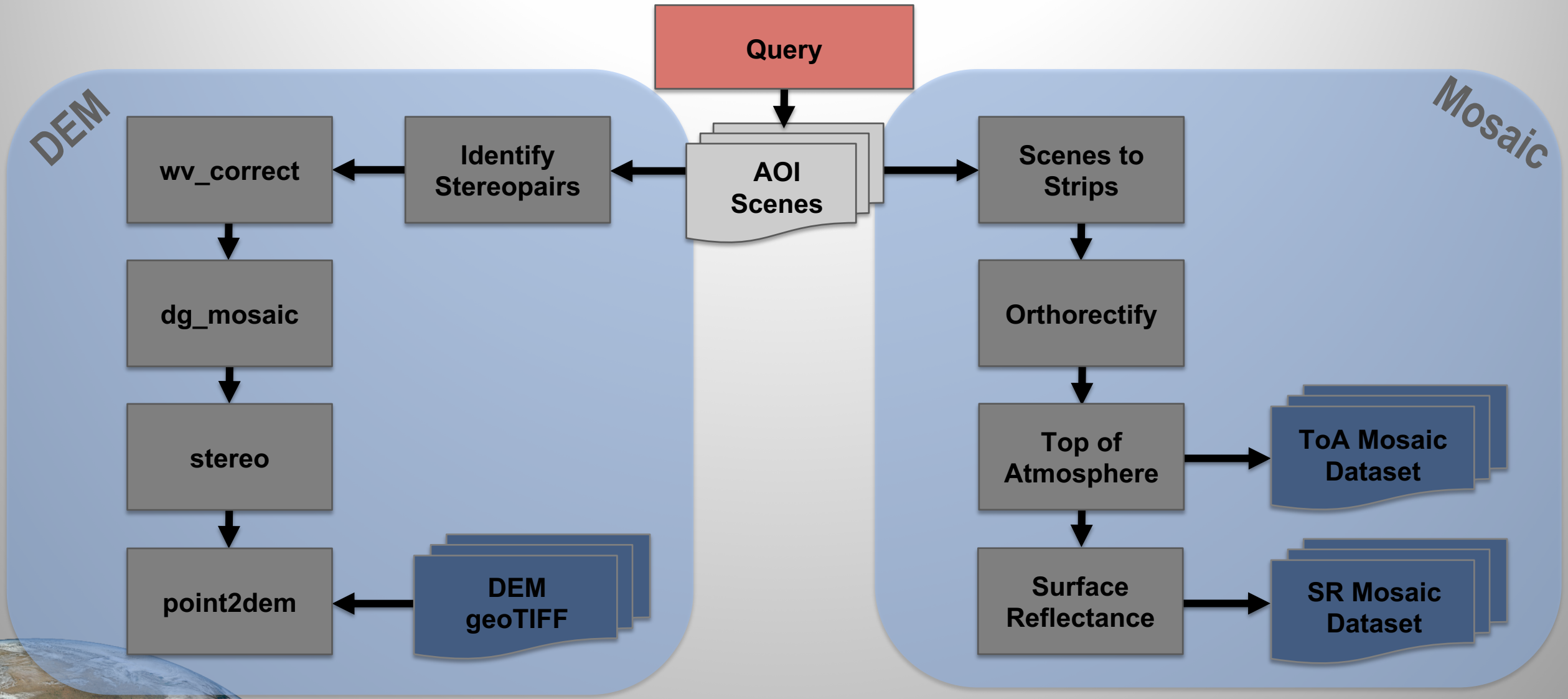
- wrapper scripts to optimize the stereogrammetry workflow

DEM workflow ***ADAPT linux cluster***



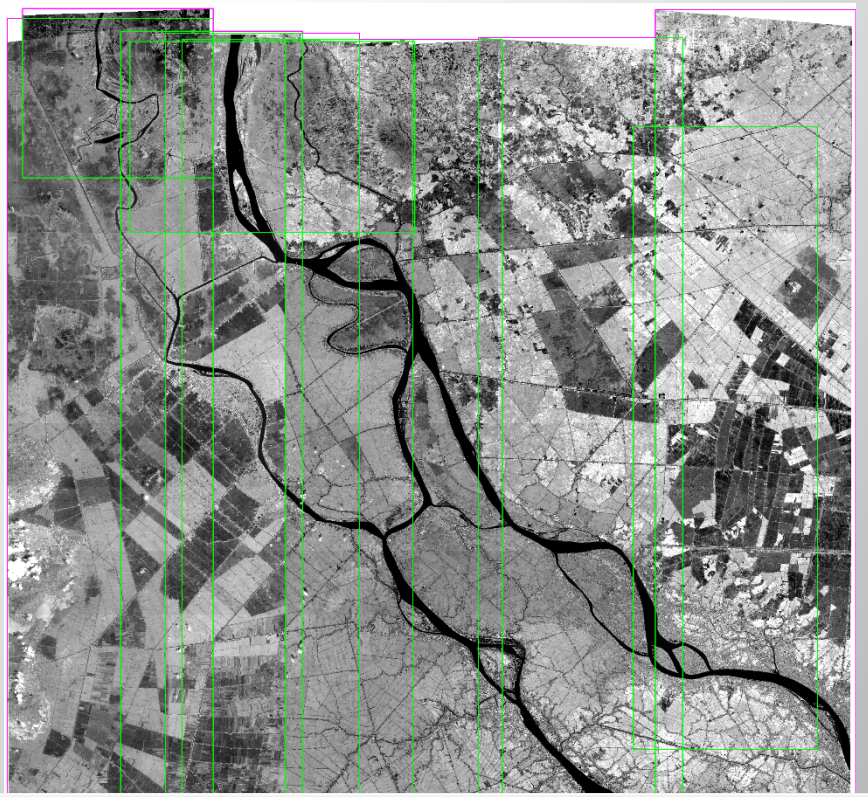
Shean, Alexandrov et al. P&RS 2016

Processing Workflow



Mosaic Dataset Outputs

- Top of Atmosphere and Surface Reflectance outputs will be delivered via ArcGIS Mosaic Datasets
  - Mosaic Datasets offers more flexibility and user control than a single output geoTIFF
  - User will be given both the mosaic dataset and underlying ToA and SR images
  - Can be converted into single-band raster image using proprietary or open-source software
  - Metadata for outputs are included in a geodatabase table



Table

request238_toa\Footprint

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Technical Development Overview

We have found through our own research that VHR data provide a wealth of site level information that enhances NASA Earth observation products and scientific results.

Our work builds on the significant progress from previous work supported by NASA's Programs:

- Terrestrial Ecology (TE)
- Carbon Cycle Science (CCS)
- Interdisciplinary Science (IDS)
- Cryospheric Sciences (CS)
- Advancing Collaborative Connections for Earth System Science (ACCESS)
- Land-Cover Land-Use (LCLUC)

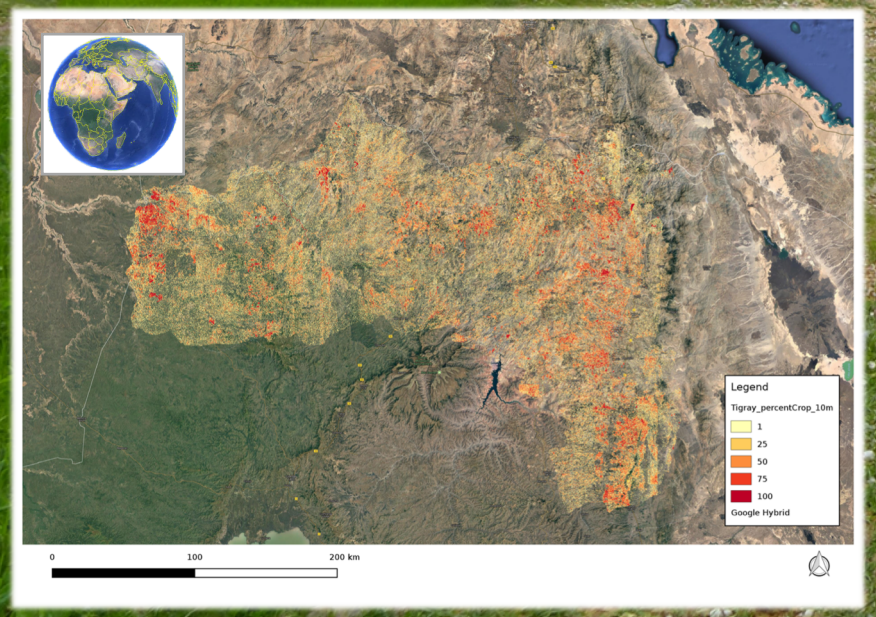
Numerous science applications can be performed with science ready VHR products!

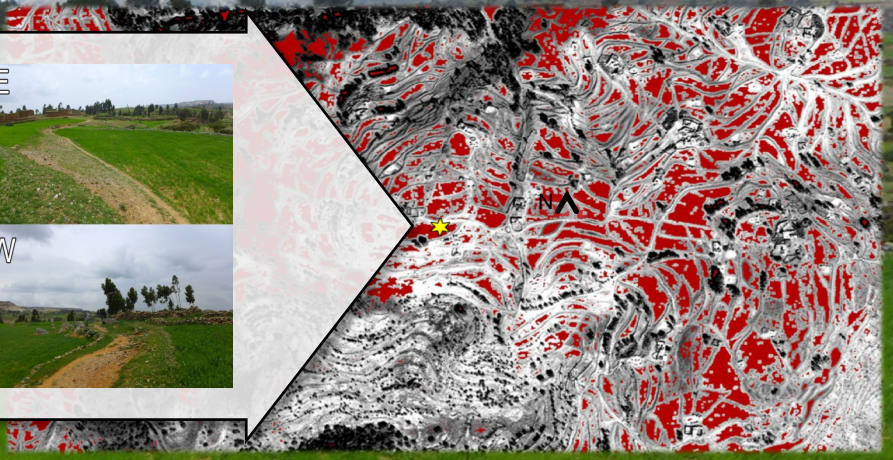
Science Examples - Mosaics – Interdisciplinary Research in Earth Science

Sub-hectare agriculture fields mapped for food security programs

Goddard SPACE FLIGHT CENTER

August 2016
Near Ruba Felege Tigray, Ethiopia 13.96N 39.73E
Photo by B. Powell





0 300 m

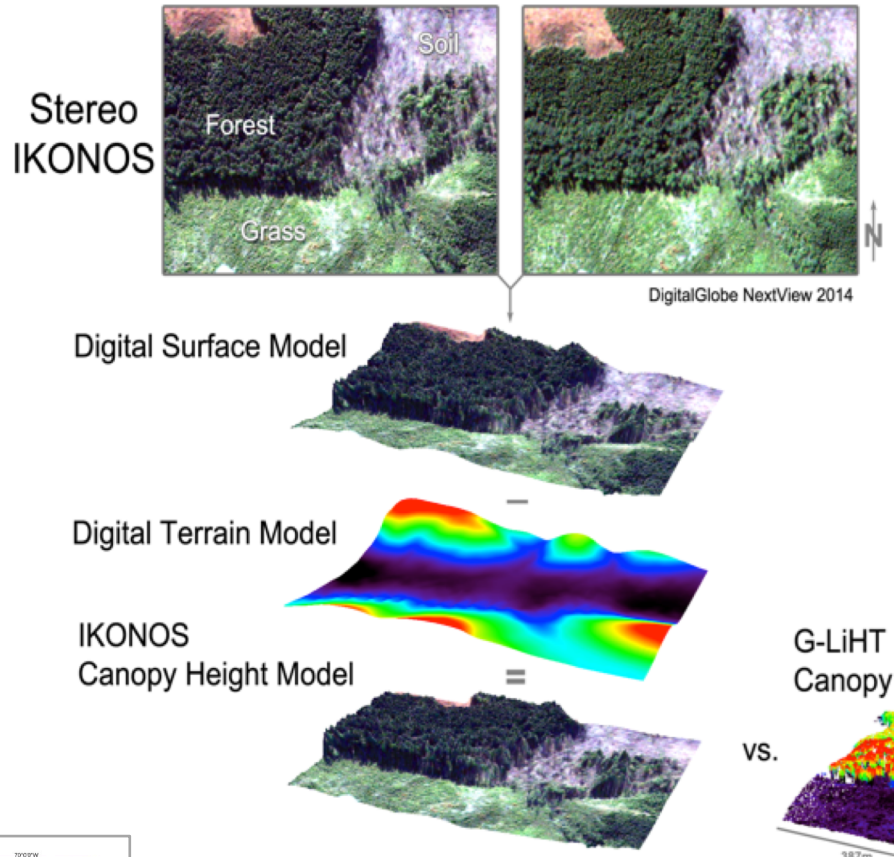
Global food production in the developing world occurs within sub-hectare fields that are difficult to identify with moderate resolution satellite imagery. Knowledge about the distribution of these fields is critical to food security programs. We developed a semi-automated high-performance computational methodology to rapidly extract cropped area from thousands of WorldView-1, and 2 images for Tigray, Ethiopia using NASA HEC resources.

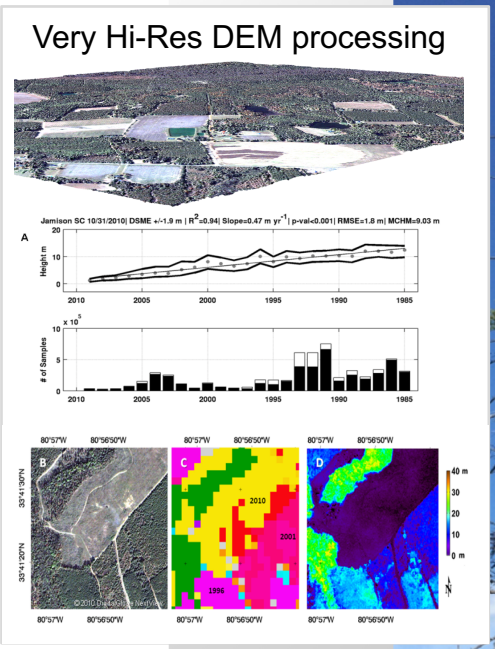
Neigh, Carroll, Wooten et al. 2018 RSE

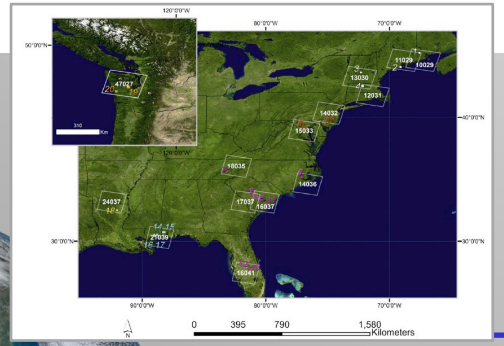
Science Ex. Cont. – DEM processing – Carbon Cycle Science

Temperate and boreal forest structure and growth

Forest carbon (C) stock is a poorly understood component of the C-cycle. Growth estimates from IKONOS and Landsat are analogous to height and carbon sequestration estimates from field data. IKONOS DEMs were found to be a reasonable alternative to airborne LiDAR. Landsat disturbance history was then used in a space-for-time swap to estimate rates of young forest growth with IKONOS in 20 locations throughout the CONUS.







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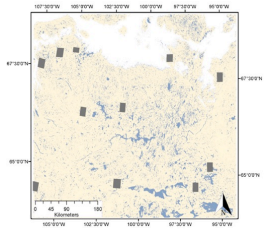
Neigh et al. 2016 RSE
Neigh et al. 2014 RS

A Core Element of the U.S. Global Change Research Program
NORTH AMERICAN CARBON PROGRAM
CONTINENTAL CARBON BUDGETS • PROCESSES • MANAGEMENT

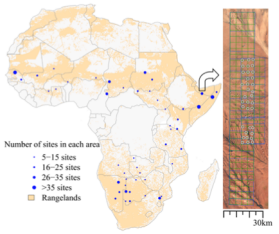
https://www.nacarbon.org/

Additional Projects/Data Use for Science

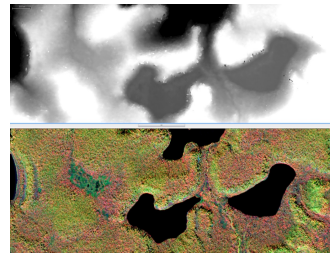
Surface water dynamics in North American Tundra – PI Carroll (TE - ABoVE)
Carroll and Laboda 2017 RS



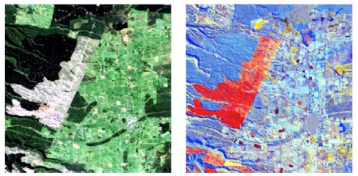
Analysis of woody vegetation properties and change across African savannas – PI Hanan (TE) Axelsson et al. 2018 JB



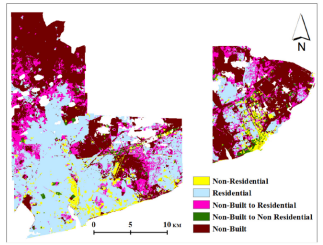
Validation of Landsat Tree Canopy Cover – PI Ranson (CCS)
Montesano et al. 2016 RS



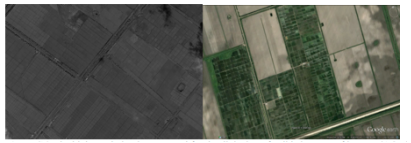
Disturbance analysis in New Zealand, mapping validation – PI (LCLUC)
de Beurs et al. 2016 IJAEOG



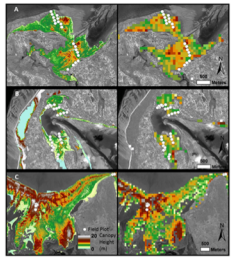
Improved fine scale urban change mapping – PI Stow (LCLUC)
Toure et al. 2018 RSE



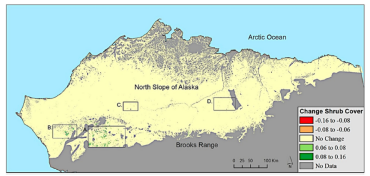
Validation of paddy rice planting expansion in NE China– PI Dong (LCLUC)
Dong et al. 2015 RSE



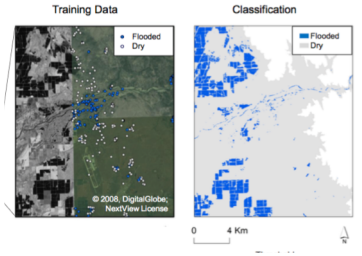
Mangrove canopy height estimation for blue carbon – PI Fatoyinbo (TE – CMS)
Lagomasino et al. 2016 RS



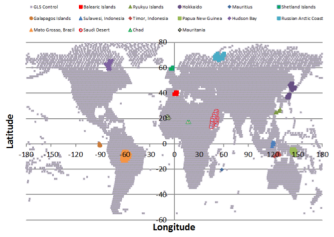
Changes in tall shrub abundance on the North Slope of Alaska – PI Chopping (TE- ABoVE)
Duchesne et al. 2018 RSE



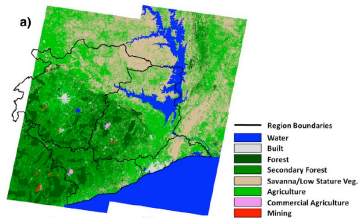
Training data for habitat mapping for shorebirds in California– PI Swenson (NESSF)
Schaffer-Smith et al. 2017 RSE



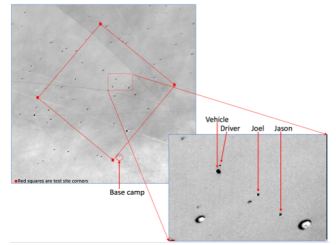
Landsat 8 Ground Control Point (GCP) improvements with WorldView – PI Storey (Landsat Science Team)



LCLUC in southern Ghana, validation – PI Stow (LCLUC)
Coulter et al. 2016 RSE



Characterizing a Cal/Val site in Bolivia – PI McCorkel (Landsat Science Team)



Science / ESD Value

There is a pool of scientists that could potentially benefit from the 3+ Petabytes of VHR data stored on ADAPT who are currently not using it.

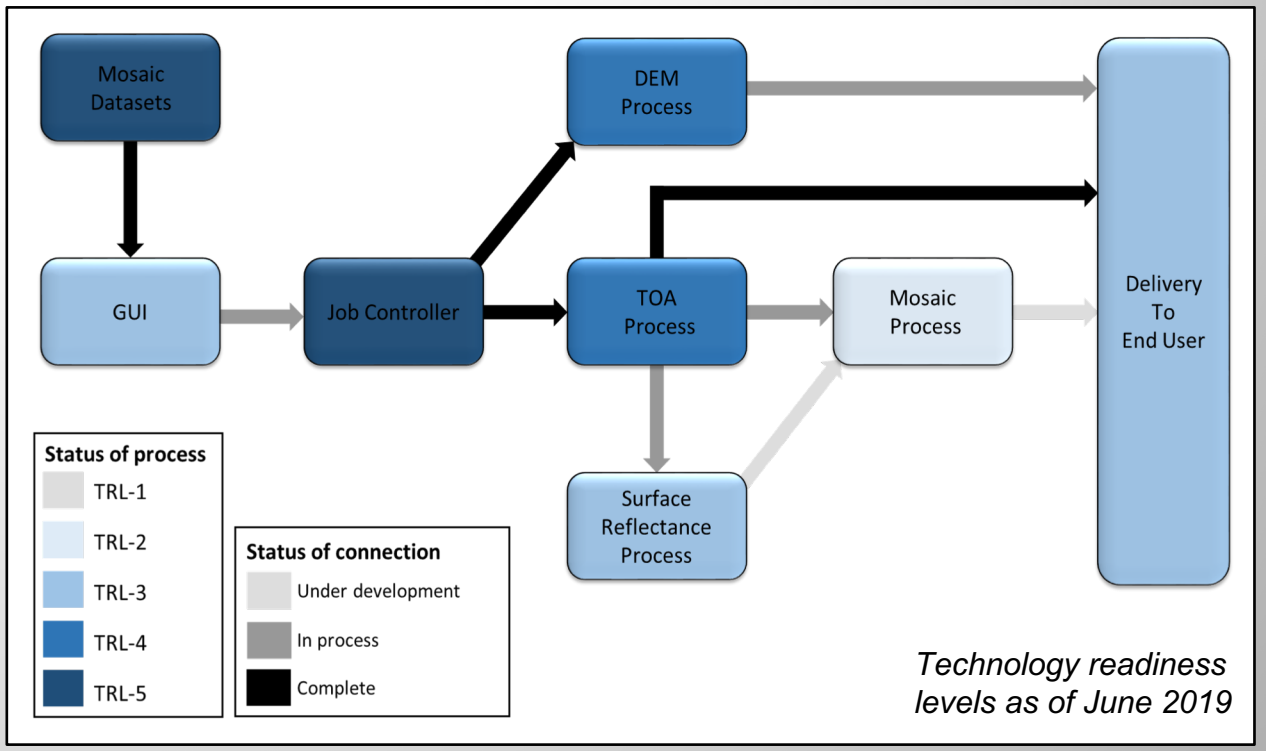
- ABoVE has > 71 funded/affiliated projects with > 430 participants, of which 38 projects and 82 individuals have requested access to VHR data. Improvements in the ease of use of the VHR data would increase the usage among this group of potential users (personal communication Dr. Elizabeth Hoy NASA ABoVE management team).

- HiMAT has > 80 scientists and has recently been funded to develop VHR DEMs for central Asia (Co-I Shean). This group is also beginning to use ADAPT for systematic analysis of data. The API would be of direct benefit to these two groups of ADAPT users.

- Pending success with these existing users there could be future expansion to users that are not currently in ADAPT such as those who are registered (300+ users from multiple NASA programs) through https://cad4nasa.gsfc.nasa.gov.

Summary

- Currently in testing version 1 of the API
- Have processed over 900 GB of Top of Atmosphere and DEM outputs through API
- Downsampled all WorldView Multispectral data in ADAPT archive for reduced resolution image previews
- We have secured funding to integrate cad4nasa into the API
- Already using the API for several NASA-funded projects:



Technology readiness levels as of June 2019

- **MuSLi (LCLUC):** Using VHR data to estimate Chlorophyll for monitoring vegetation function and productivity
- **Vietnam (LCLUC):** Applying VHR data to model patterns of rice agriculture as a proxy for cultural and religious practice, to understand the influence of commercial and government funding on traditional rice cultivation
- **Myanmar (LCLUC):** Mapping land cover at VHR to identify forest fragmentation and agro-industry as potential areas of human exposure to malaria. Results will be put into a human movement model to understand how land use land cover effects risk of exposure to malaria.

Thank You

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