LCLUC and High-resolution data update.

Chris Justice (UMD)
Very high-resolution commercial imagery available for NASA-funded research

- The National Geospatial-Intelligence Agency's extensive archive of commercial satellite data are available to you free of cost
- Licensed under NextView contract (can be shared with those supporting USG interests)
- 5 sensors available, MS and panchromatic (0.5 to 5 m resolution), NITF format, extensive global coverage
- Go to [http://cad4nasa.gsfc.nasa.gov](http://cad4nasa.gsfc.nasa.gov) to register and submit requests (LCLUC grant number needed)
- See poster

Jaime Nickeson, NASA-GSFC
Mapping Urbanization

- High resolution data is used as ground reference
Mapping Urbanization: Urumqi

- Quantifying and understanding urban expansion
- Identify sinkhole areas that are not suitable for urban land use
Use of high-resolution NGA-provided commercial datasets in LCLUC project: The Impact of Disappearing Tropical Andean Glaciers on Pastoral Agriculture

PI: Dan Slayback, SSAI/NASA Goddard
ROSES 2009, project period July 2011-June 2014

Access to cost-free high-resolution commercial imagery via NGA (and CIDR (USGS)) is improving the quality of the science returned by this project by:

1. Permitting much easier validation of landcover changes observed in Landsat in remote mountainous regions that are difficult, and expensive, to visit in person.

2. Providing detailed high-resolution landcover information for our 5 field sites, useful for planning field activities and understanding landcover at the sub-Landsat pixel scale (where small ponds are frequent)

3. Allowing us to generate detailed DEMs for these sites from stereo imagery (via CIDR requests), which greatly improve understanding of the local hydrology at the field sites. SRTM and GDEM (ASTER) are often the only available alternative, but are too coarse in spatial resolution to be useful.

Obtaining the data we have used via commercial channels would have increased the budget for this project by a substantial margin – at least $100k, and possibly much more. Such costs would not have been within the budget limits of the original project proposal, and so were not included,
Glacier change validation

Landsat 2006 with classified glacier area polygons

GeoEye 2010, displayed with a quick orthorectification, allows:

• Visual assessment of overall accuracy (despite further loss of glacier since 2006).
• Verification that glacier edges are clean, and not debris-covered.

Slayback et al. NASA/GSFC
DEM Generation

GeoEye-1: First stereo view

DEM Generation

GeoEye-1: Second stereo view

DEM at 2 m resolution

Slayback et al. NASA/GSFC

Orthorectified image draped on generated DEM
WorldView2 enables detailed glacier margin mapping
Slayback et al. NASA/GSFC

Worldview-2 June 16, 2010 <1 m

Huayna-Potosi Glacier Bolivia

Landsat 5 TM August 17, 2010 30 m

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Relationship between spatial patterns of land cover types and surface temperatures (Soe Myint, NASA funded Project: 11-IDS11-4).

- Spatial arrangement and LC type
- Impact on Surface and Air Temperature

**Worldview 2 (NGA)**

**Classified Output (Ecognition)**

Las Vegas, Nevada

Soe W. Myint, ASU
Mapping agricultural expansion across Monsoon Asia

• Training data for classifier: “NGA High Resolution”
• Evaluating scaling & data fusion: “NGA”, Landsat TM, ALOS PALSAR

Xiangming Xiao
University of Oklahoma
Mapping Agricultural Land Use - Karamoja Uganda

- Current land use dataset is Africover2000 (FAO, 2000) derived from 30m Landsat - poorly represents subsistence Cropland
- Average field size in ~1.7 hectares
- High resolution data (Worldview 2 data) is being used to map land use and update FAO Africover2000 product

Nakalembe, Barker (University of Maryland)
Preliminary agricultural land use mapping using World View 2 data
Hi- resolution Data for mapping Carbon in sparsely -treed landscapes.

• Evaluation of methods in various Landscape types
  – Savannah and woodlands
  – Agroforestry and trees on farms
  – Orchards and plantations

• Tree crown area algorithms
  – Watershed segmentation → merge algorithms → rule-based classification
  – Modified GEOBIA approach

Skole et al. , Michigan State University
Methods

Modified GEOBIA

- Very-high resolution satellite data (0.5 m pixels)
- Modified Geo-Object-Based Image Analysis (GEOBIA)
  • Veg./Non-veg. spectral bootstrapping
  • Compute gradient vector field (GVF)
  • Crown peak detection
  • Crown boundary detection
  • Compute crown area (diameter/radius)
- Spatial data processing
  • Map crown peak locations (lat./long.)
  • Build buffer polygon file using radius values
- Compute tree carbon
  • GEOBIA computed crown area \( \rightarrow \) DBH \( \rightarrow \) Biomass (carbon) allometry
- Mapping and Analysis

Field Measurements

- Biometry relationships
  • Crown area to DBH for estimating biomass using standard allometry
  • Crown area to biomass (carbon)

Watershed \( \rightarrow \) Rules-based

- Pan-sharpening image
- Mean Filtering
- ENVI Image segmentation and Merge (Scale 1)
  - Image Segment (Scale 1)
  - Rule-base classification (Single tree and Cluster tree)
  - Build Image Mask
- Single tree crown
- Tree Crown Map
Watershed → Rules-based: Vietnam (Litchi orchards) – 0.6 m pan-sharpened QuickBird data

Above right and left
(a) No treatment
(b) 3 x 3 mean filter

Left – results from first order Rules-based classifiers.

First Order Classifiers
• For Single tree crown
  Rule 1.  Area : 4-40 m$^2$
  Rule 2.  Roundness : >0.3
  Rule 3.  NIR : 600-760
• For Clusters of trees
  Rule 1.  Area : <40m$^2$
  Rule 2.  NIR : 600-760

David Skole,
Michigan State University
Final map of individual tree crown areas and clusters of trees
Modified-GEOBIA: Kenya – 0.6 m Pan QuickBird data

David Skole, Michigan State University
Sparse Woodlands – Rukiinga Ranch REDD Project, Voi, Kenya

25 ha
79.09 tC
3.16 tC/ha

David Skole, Michigan State University
Kenya – Mapping trees on farms

David Skole, Michigan State University

155 ha
1418.83 tC
9.15 tC/ha
Cropland burned area mapping in Russia

Collaborative project w. USDA aimed at quantifying amount of Black Carbon emissions from agricultural fires in Russia

VHR data are critical in:

- Locating and characterizing cropped areas
- Validation of active fire product
- **Assessing pure pixel signature separability of burned and ploughed fields**
- Developing training and validation samples to drive MODIS-based cropland burned area algorithm development

RIGHT: Sample plot of mean and 1 SD separability of burned (red), ploughed (blue) and containing crop residue (grey) fields from Quickbird imagery in European Russia

ABOVE: Quickbird multispectral image of an actively burning field in European Russia with superimposed MODIS active fire detections

Loboda, Hall (UMD), McCarty (USDA)
Health shocks as a driver of LCLUC

• **Objective:**
  – While the effects of land use on health are well researched, very little is understood about the reversal of this mechanism.

• **Methodology:**
  – We are combining health, socioeconomic and hi-resolution satellite data to examine **how health shocks suffered by agricultural households may contribute to land use change.**
  – We are examining how households respond to the shock and examine potential change in spectral signature from satellite imagery.
  – We will then correlate fluctuations in agricultural land with prevalence of adult health shocks, and then use survey and qualitative interviews to help establish the potential causal link while controlling for other drivers of land use change.

• **Importance of hi-resolution data:**
  – Data of this resolution are necessary given the spatial scale of the **average farm size (1.66ha in Mozambique).** This will assist with the change detection analysis that examines changes in land use. The image from the next slide depicts a collection of farms under an irrigation scheme in this area.
Chokwe, Mozambique: 05/24/2012

GeoEye-1 (OrbView-5)
Source: NGA
NGA fine resolution data support the ground truth data collection effectively in our study.

Xiangming Xiao; University of Oklahoma
Higher resolution data enable identifying the small land parcels in fragmented and complex landscapes.

Xiangming Xiao; University of Oklahoma
Expansion of tall shrublands in Siberian tundra: Use of NGA data

Gerald Frost, Howard Epstein, University of Virginia

RECENT PUBLICATION USING NGA DATA
Frost GV et al. 2013 Patterned-ground facilitates shrub expansion in Low Arctic tundra
Environmental Research Letters 8 015035

STUDY AREAS
- Approximately 10 NGA data requests for northwest Siberian Low Arctic

Gerald Frost, Howard Epstein
University of Virginia
NGA Data Applications

Tundra shrub change detection using 1960s high-resolution imagery

Gerald Frost, Howard Epstein (UVA)
NGA Data Applications

- NGA data enable us to identify local-scale mechanisms for landcover change. Many of these mechanisms are hidden at “sub-pixel” scale in other data sources (e.g., Landsat)
The Urban Transition in Ghana and Its Relation to Land Cover and Land Use Change Through Analysis of Multi-scale and Multi-temporal Satellite Image Data

Project Scope and Objectives Pertaining to Hi-Res Satellite Data

- Assess LCLUC and its effect on demographic and quality of life factors for four major urban centers during this time period.

- Intra-urban identification of LCLUC based on high spatial resolution image data from QuickBird, WorldView, IKONOS and Geoeye commercial satellites.

- Emphasis on the effects of LCLUC on quality of life indicators such as child mortality, slum indices, and food security, within four of the major cities of Ghana.
The Urban Transition in Ghana and Its Relation to Land Cover and Land Use Change Through Analysis of Multi-scale and Multi-temporal Satellite Image Data

Characteristics of commercial high spatial resolution satellite (CHSRS) systems and data.

<table>
<thead>
<tr>
<th>City</th>
<th>Satellite Sensor</th>
<th>Temporal Coverage</th>
<th>Spectral Bands</th>
<th>Spatial Resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accra</td>
<td>QuickBird-2</td>
<td>2002, 2010</td>
<td>VNIR</td>
<td>2.4 m MS, 0.6 m PAN</td>
</tr>
<tr>
<td>Kumasi</td>
<td>IKONOS-2</td>
<td>2001, 2009</td>
<td>VNIR</td>
<td>4 m MS, 1 m PAN</td>
</tr>
<tr>
<td>Cape Coast</td>
<td>OrbView-3, IKONOS-2</td>
<td>2005, 2009</td>
<td>VNIR</td>
<td>4 m MS, 1 m PAN</td>
</tr>
<tr>
<td>Obuasi</td>
<td>IKONOS-2</td>
<td>2008</td>
<td>VNIR</td>
<td>4 m MS, 1 m PAN</td>
</tr>
</tbody>
</table>

Figure 5. Vegetation change between 2002 and 2010 derived from classification of QuickBird multispectral data. A seven percent area-wide decrease in vegetation cover occurred in this period, with greatest relative decrease in slum areas.

Douglas A. Stow, San Diego State University
Housing Quality Index (Census) vs. % Vegetation (QuickBird) - Neighborhoods in Accra, Ghana

\[ y = 21.587x - 28.839 \]

\[ R^2 = 0.7327 \]

Connecting QuickBird derived metrics to socioeconomic survey data

Douglas A. Stow et al.
San Diego State University
Multi-sensor fusion for measuring climate variability in South Asia

- Mapping cropping intensity of smallholder agricultural fields across India from 2000 to the present using MODIS and Landsat data
- Using high-resolution Quickbird and WorldView-2 imagery (NGA database as validation of “true cropped” area)
Cropped area during winter 2009-10 in Gujarat, northwest India quantified using our four methods: (C) Landsat threshold, (D) MODIS peak, (E) MODIS temporal mixture analysis, and (F) MODIS hierarchical. High resolution Quickbird data (A and B) were used to validate our four models. Jain et al. Remote Sensing of Environment. In press.
The GLS-IMP is attempting to map global urbanization at 30m Landsat scale for the first time.

1) Map %Impervious cover at global 30m resolution using GLS 2010, 2000 data.
2) Map areas of global urban expansion between 2000 and 2010.

We use the NGA imagery to provide training and validation. This project would likely not be possible without access to a global archive of very high resolution satellite data.

- We have acquired a selected archive of NGA data across all continents (700+, see figure).
- We use the data to produce training masks of impervious/non-impervious cover across each continent using Hierarchical Image Segmentation.
- The high resolution data are aggregated to 30m resolution of Landsat for training a regression tree algorithm (~2.4M training pixels for Europe alone).

Caveats:
- The ‘processed’ archives from NGA such as ‘CitySphere’ not useable for science.
- Currently we are developing our own orthorectification software to more effectively process our data and to do it in an automated, consistent fashion.
- Processing and pre-processing of NGA data, including searching and ordering is difficult, not geared towards scientific uses, and can be a significant resources sink.
Training Mask Examples

Glasgow, UK

Dobryanka, Russia

Jedlinsk, Poland

El Toro, Spain

Eric Brown de Colstoun, NASA-GSFC
Global Soybean Area Project

Objectives
- Employ multiple resolution data: MODIS, Landsat, RapidEye and field data to estimate national-scale crop area by type
- Test a generic approach to estimate cultivated soybean area in the USA, Brazil, Argentina and China (accounts for c. 90% of global soybean production)
- Illustrate the viability of remote sensing-based global crop type area estimation using a sampling approach

Approach
- MODIS used for generalized models to generate per nation/sub-region to indicate within growing-season soybean cultivation based on sub-pixel percent cover training data
  - The models estimate percent soy-cover and enable the stratification of national-scale cropland growing regions for sampling purposes
- S1- Landsat samples used to map per sample block soybean cultivated area
- S2- RapidEye allows for per country/region calibration of Landsat area estimates
- The Landsat sample blocks are then analyzed to quantify national-scale crop type area

Matt Hansen et al. UMD
High, medium and low soybean strata using MODIS

Red=high (>19.8%), orange=medium (7.2-19.8%), yellow=low (0.5-7.2%)
Landsat sample blocks (S1)
3-4 acquisitions during growing season
RapidEye sample blocks - S2

Red=high (>19.8%), orange=medium (7.2-19.8%), yellow=low (0.5-7.2%)
RapidEye – 140 acres, Landsat 126 acres
Preliminary Results

Calibration of Landsat with Rapid Eye
Rapid Eye vs. Landsat Area estimates per Block

\[ y = 0.862x + 0.0703 \]

\[ R^2 = 0.9273 \]

Comparison of Area Estimates using Landsat sample blocks vs. wall to wall Landsat based estimate

\[ y = 0.733x \]

\[ R^2 = 0.8386 \]

Hansen et al
Developing Tools for Hi-resolution Automated Classification (SIAM™)

World View 2: Brazilia

Stage 1 Automated Spectral Classification

Fig. 2(a). WorldView-2 (WV-2) image of Brazilia (Brazil), spatial resolution: 2 m, acquisition date 2010-08-04, radiometrically calibrated into TOA reflectance values and depicted in false colors (R: 5; G: 7; B: 2). Default image histogram stretching: ENVI linear stretching 2%.

Fig. 2(b). Q-SIAM™ preliminary map of the WV-2 image shown in Fig. 2(a). Spectral categories are depicted in pseudo colors.
Automated Spectral Categories SIAM™

Fig. 2(c). Zoom of the WV-2 T2 image, 2 m spatial resolution, acquisition date 2010-08-04, radiometrically calibrated into TOARF values shown in Fig. 2(a), depicted in false colors (R: 5, G: 7, B: 2). Default image histogram stretching: ENVI linear stretching 2%

Fig. 2(d). Zoom of the Q-SIAM™ preliminary map, shown in Fig. 2(b), corresponding to Fig. 2(c). Spectral categories are depicted in pseudo colors. Map legend: see Fig. 2(b).

Fig. 2(e). 4-adjacency cross-aura measure generated from the Q-SIAM™ preliminary map, shown in Fig. 2(d). Cross-aura values range in (0, 4).

Fig. 2(f). Binary vegetation mask generated from the Q-SIAM™ preliminary map, shown in Fig. 2(d).
Recommended Two Stage Approach

Spaceborne / airborne MS image rad. cal. into TOA reflectance or surface reflectance values

First-stage preliminary classification (fully automated SIAM™)

Multi-granule pre-classification maps

Multi-scale segmentation maps

Second-stage hybrid driven-by-knowledge contextual classification (class- and application-specific): Divide-and-conquer classification approach

Land cover classification map

1\textsuperscript{st}-stage deductive pre-classification

Semantics information gap to fill up, from sensory data to land covers: \textasciitilde 50%.

2\textsuperscript{nd}-stage hybrid classification

Semantics information gap to fill up, from sensory data to land covers: \textasciitilde50%.

Stage zero for image pre-processing is not shown.

Baraldi UMD
Use of NGA high resolution imagery in NASA USAID CARPE - Congo Basin Research
Potapov, Hansen, Tyukavina, Barker, Molinario (UMD)

1) Validate Landsat scale wall-to-wall remote sensing based maps of forest cover loss in the Congo Basin – the FACET product of Potapov et al 2010.

2) Sampling design to analyze a statistically significant portion of the DRC and assess:
   a) The vegetation classification of “non-forest”, “secondary” and “primary” forest classes of the “rural complex” as well as
   b) The spatio-temporal cycle of shifting cultivation: how it affects forest cover.

First step develop necessary Hi-Resn tools:
- Data block interrogation and multi-temporal coverage diagrams
- Perform image ortho-rectification, file type conversion and radiometric calibration
- Testing Automated Classification SIAM Stage 1 quick looks and stratification
A considerable amount of forest cover loss in the DRC occurs in the range of 1-3 Landsat pixels.

- Potapov et al. 2010 estimate the median clearing size at 1.4 ha.
- Need high resolution to further study the slash and burn forest cover dynamic.
CARPE’s VHR Acquisitions

Area remaining to be filled: Requested 11/2012

Molinario and Braker, UMD
Generic Hi-Resn Image Processing Tools

• Metadata extraction
  – to text files, .shp and PostGREs-PostGIS DB
• Basic footprint creation (.shp)
• Cloud free footprint creation (.shp)
• Hyperlinks for footprint/image visualization
• Multi-temporal image querying
• Renaming of imagery to a standard naming convention
• One click, batch Orthorectification *
  – File type conversion from NITF to GeoTiff or ENVI standard
• One click, batch TOA radiance and TOA reflectance calibration **
• One click, batch SIAM processing on a directory of images #

* Code provided by Claire Porter UMN, and adapted
** Calibrators provided by L. Boschetti, A. Baraldi and modified and adapted by Brian Barker, UMD
# Trademarked software by A. Baraldi, UMD

Molinario, Barker, Baraldi et al. (UMD)
• Metadata is extracted from the image through a python script and provided in a simple txt file.
• The txt file can then be referenced in other processes such as footprint creation or radiometric calibration.
Basic Footprints

- The basic footprints can be tailored to provide any portion of the metadata that is required by the user. Currently image acquisition date, cloud cover, satellite platform, and image name are primarily used.
Cloud Free Footprints

- The cloud free footprints use the embedded cloud mask within the NITF file in order to create a footprint that shows the location of cloud free areas.
- This gives the user a better understanding of the usable portion of the imagery.
Quicklooks: Hyperlinks for Footprint/Image Visualization

- The hyperlink setup allows for a quick visualization of a low resolution jpeg of the satellite image, helping to better judge the quality of the specific image.
Multi-temporal Image Querying

- Use PostGIS to perform spatial queries on the imagery footprints.
- A raster visualization of data density.
- Each 1km² cell contains the number of multi-spectral, cloud free data overlapping that specific location.
- A shapefile format of this visualization is also available, containing the list of overlapping image dates for each location within the attributes.
Batch Orthorectification

- We are able to batch perform orthorectification on the imagery using a modified version of a python script from Claire Porter at the Polar Geospatial Center.

- Within this script we are also able to convert the image format from NITF to GeoTiff or to an ENVI standard format. Making the imagery easier to use across different image processing software that might not be able to handle the NITF format.

- We have adapted the scripts to work on the Linux platform. Natively they rely on the OSGEO GDAL and Python Bindings in a windows environment.

- Great collegial support from Claire Porter of PGC @ UMN
DEM Acquisitions

- For the orthorectification process a suitable DEM is required.

- For CARPE, we acquired a restricted 30m Central Africa SRTM DEM and repaired areas of missing data with data from ASTER GDEM V2 tiles.

- For external projects requesting our assistance, we use a DEM provided by the requesting project, however we are able to acquire, build, and in some cases repair a DEM for accurate orthorectification if needed.

- Within the U.S. a 10m NED can usually be acquired through the USGS, outside the U.S. a 30m DEM can be build from several ASTER Global Digital Elevation Model Version 2 (GDEM V2) tiles.
Uncorrected 30m restricted SRTM DEM – Central Africa
Orthorectification with a standard SRTM DEM results in holes
ASTER-corrected 30m SRTM DEM orthorectified image
TOA Radiance and TOA Reflectance Calibration

• Ikonos-1, Quickbird-2, Woldview-2 calibrated using IDL scripts provided by Andrea Baraldi and adapted to our environment.

• Orbview-5/GeoEye-1 calibrator structure provided by Andrea Baraldi, and modified to Orbview-5/GeoEye-1 by Brian Barker.
  – Through direct contact with GeoEye engineers and assistance from Andrea Baraldi, we were able to identify the correct OV05/GE01 exo-atmospheric irradiance and band bias values needed.
  – In addition, Brian Barker was able to identify for the GeoEye Engineers a time period where their product was incorrectly writing the irradiance and band bias values within the metadata.
  – The calibrator was adapted to OV5/GE1
SIAM™ Spectral Stratification

• Developed script to run SIAM™ in batch on a directory of images for CARPE/Congo Basin.

• Once images are brought to TOA Reflectance we are able to run them through the unsupervised automatic spectral rule classifier Satellite Image Automatic Mapper (SIAM™) by Andrea Baraldi, which outputs maps classified and labeled in 52 spectral classes.

• We can then regroup those classes in order to obtain a specific land cover classification and differentiate certain areas such as rural complex vs. intact forest.
Example of SIAM Stratification

- Bare Ground vs. Vegetation Extraction

Original (3-2-1)  Original (4-3-2)  SIAM (all 52 classes)  Manual expert interpretation and grouping: Bare Ground vs. Vegetation
NASA discussions with NGA Ongoing re. data access for NASA Science (Tucker, Nickeson et al. GSFC - Berrick, Maiden HQ)

• For data already acquired by US Government (largely NGA)

• Registration required & Data Use Agreement Form must be signed

• Data for scientific research
  • Restricted for use within NASA-funded projects only
  • No transfer to unaffiliated parties
  • No commercial use
NGA Commercial Archive Data

Access to High-Resolution Data for NASA Earth Science Investigators

1. Register
2. Complete form
   Requires grant number
3. Read about our system, sensor
   Information, and coverage maps

Welcome Members

Please note the limitations of our system and read the content below before submitting a request.

When requesting data you should be aware of some of the limitations of NGA's WARP (Web-based Access and Retrieval Program) primary interface to their data archive. This archive includes commercial imagery products such as Worldview 1 and 2 and GeoEye (GeoEye 1, IKONOS). See the 'Sensor Information' for more details on these sensors.
Submit a Request

After verifying your User Profile, you can submit an imagery request.

Orders generally take 1-2 weeks to fill, depending upon the order type and backlog.

Once received, data are placed online and download instructions are provided.

Data must be kept secure with limited access and all users must be tracked.
Summary Hi Resn Data for LCLUC Research

• Fine Resn data opens up a new dimensions for LCLUC Research
• Hi-Resn Data are being ordered by LCLUC Community and starting to be used in a range of science applications
• Anticipating considerable growth in demand for data
• Facility at GSFC currently providing data ordering/brokering services – effort needs to be right-sized for the demand
• Also need a suite of additional Data Services and Tools for Analysis (spectral and textual) to reduce redundancy and burden on users (especially for large orders - data bricks)
• LCLUC Program should continue to promote and support hi-resolution data analysis for its projects