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Global Forest Cover Change

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Overview

• Goals
• Challenges
• Where we are
• Questions
Project Goals

- Global, fine resolution (<100 m) surface reflectance (SR) ESDR
  - For 1990, 2000 and 2005

- Global, fine resolution (< 100 m) forest cover change (FCC) ESDR

- Global, 250 m, forest cover change (VCF FCC) ESDR
  - For 2000 to 2005, using vegetation continuous fields
Overall Processing Flow

Major Inputs
- Landsat images
  GLS 1975, 1990, 2000, 2005
  Supplemental images
- 250 m MODIS reflectance data
  2000-2005

Algorithms
- Land surface reflectance
- Change detection and fragmentation algorithms
- Consistency control
- VCF-based FCC mapping

Major Deliverables
- SR ESDR
  1975, 1990, 2000, 2005
- Forest Cover & Fragmentation Change ESDR
  1975 – 1990
  1990 – 2000
  2000 – 2005
- 250 m VCF-Based FCC ESDR
  2000-2005, annual

Validation
- Using AeroNet MODIS
- Comprehensive validation approaches
Available Data Collections

Landsat data collections are available:

- Global Land Survey (GLS, formerly known as GeoCover)
- At 30m resolution (1990-2005) and 60m resolution (1975)
- Global coverage of imagery

Several collections of elevation imagery available:

- SRTM (90m global)
- ASTER-DEM (30m global)
- locals

GLS1975  GLS1990  GLS2000  GLS2005  GLSDEM-90m
Challenges: Input Data

• GLS 2005:
  – Leaf-off scenes
  – Cloudy
  – SLC-OFF

• GLS 2000
  – Leaf-off scenes
  – Cloud
  – Bad data (now replaced)

• GLS1990
  – Leaf-off scenes
  – >50% missing/incorrect calibration
  – Waiting on USGS repatriation

• GLS1975
  – Entire archive needs to be replaced
Challenges: Input Data

- **GLS 2005:**
  - Leaf-off scenes
  - Cloudy
  - SLC-OFF

- **GLS 2000**
  - Leaf-off scenes
  - Cloud
  - Bad data (now replaced)

- **GLS 1990**
  - Leaf-off scenes
  - >50% missing/incorrect calibration
  - Waiting on USGS repatriation

- **GLS 1975**
  - Entire archive needs to be replaced
  - Very different calibration values from different GRS
Percent land areas (%) not covered by GLS images.

<table>
<thead>
<tr>
<th>Continent</th>
<th>GLS1975 %Area</th>
<th>GLS1990 %Area</th>
<th>GLS2000 %Area</th>
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<td>2.88</td>
<td>0.66</td>
<td>0.66</td>
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Noojipady et al.
Filling a Major Hole in GLS 1975

- No GLS 1975 image for the entire northern SA
- Suitable images exist at INPE for most of the gap
  - Have obtained 475 L1G images from INPE
  - Will orthorectify using GLS standards
  - All improvements to GLS will be made available
Acquisition year range of the GLS datasets
Summary of image-to-image corregistration accuracy of the GLS datasets measured using the GLS 2000 dataset as the reference.

<table>
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<th>Dataset</th>
<th>Total RMSE (Line)</th>
<th>Total RMSE (Sample)</th>
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<td>GLS-1990</td>
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<td>GLS-2005</td>
<td>4.69 m</td>
<td>5.09 m</td>
<td>5.89 m</td>
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</table>
Surface Reflectance (SR)

• First Global Surface Reflectance product at Landsat resolution:
  ✓ GLS2005
  ✓ GLS2000
  ✓ GLS1990

• GLS2000 and GLS2005 SR available for download via GLCF @ www.landcover.org since June 2011.
Atmospheric Correction

Based on MODIS/6S radiative transfer approach

- water vapor from NCEP (2.5deg) re-analysis data
- ozone from TOMS/EP-TOMS/TOVS/OMI
- topography-dependent Rayleigh correction

Aerosol optical thickness estimated from imagery using the Kaufmann et al (1997) “Dense, dark vegetation” approach

- Average Landsat TOA to 1km resolution; select “valid” targets for AOT
  - NDVI > 0.3
  - 2.2 mm TOA < 15%
  - screen for cloud, snow/ice, salt playas
- estimate blue surface reflectance = 0.33*(2.2 μm TOA reflectance)
- difference between TOA_{blue} and SR_{blue} gives AOT_{blue}
- interpolate valid targets across image
- use continental aerosol model to calculate AOT spectrum
Total of 75.3 terabytes downloaded

Total of ~73,000 scenes downloaded
Global mosaic of GLS 2000 SR

Landsat 3, 2, 1 bands
Global mosaic of GLS 2000 SR

Landsat 4, 3, 2 bands
Cape Cod, USA (72W - 67.5W, 41N - 46N)
Ireland, (11W - 5W, 51N – 55.5N)
The phenology difference of the GLS images causes visual patch in the global SR mosaic.
1516 GLS2000 images eligible to be replaced under 70% Rule.
812 GLS2005 images eligible to be replaced under 70% Rule.
GLS2000 or GLS2005 images eligible to be replaced under 70% Rule.
Web app System Diagram

CSV from IDL Module

User input

Search Conditions – Date/Month/Year, Quality, Cloud, Path/Row

Perform Search

Data Base

Data Base update tool

Metadata

Landsat 7 ETM+ (SLC-on)
Landsat 7 ETM+ (SLC-off)
Landsat 1-5 TM
Landsat 4-5 MSS
Landsat 1-3 MSS

WRS Tile Update

Path/Row, Date range of growing season

Search results

Updated WRS shp file

Shown as Table
Replacement Scenes

GLS 2000
284 Replacement / 424 scenes need to be replaced

GLS 2005
252 Replacement / 435 scenes need to be replaced
Compared Landsat SR results with MODIS SR daily and NBAR.  

- Overall sanity check for erroneous output

Results are mostly consistent with MODIS SR data.

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<th>Band</th>
<th>Num</th>
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<th>Intercept</th>
<th>$R^2$</th>
<th>RMSD</th>
<th>RMSD_S</th>
<th>RMSD_U</th>
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SR processing result (GLS 2000 ETM+)
SR processing result (GLS 2005 ETM+)
SR processing result (GLS 2005 TM)
SR: Papers


Forest Cover Change (FCC)

• Develop a tri-decadal Global FCC leveraging GLS collection.
Forest Cover Change 2000-2005 v0.0
Forest Cover Change 2000-2005 v0.2

Funding source: NNH06ZDA001N-MEASURES
FCC Challenges

• FCC 2000 – 2005:
  ✓ Phenology
  ✓ Improved cloud, cloud shadow & water detection
  ✓ Terrain Illumination correction
  ✓ Commission errors:
    ✓ Large crop regions
    ✓ Semi arid/spare forests
FCC Challenges: Solutions

• Phenology:
  – Figure out global start and end of peak phenology
  – Harvest Landsat metadata archive to find phenologically optimized scenes
For each pathrow

16-day MODIS NDVI

MODIS LC

Overlaid

40% forest?

Yes

40% evergreen?

No

40% Deciduous?

Scene NDVI

Forest NDVI

Evergreen NDVI

Deciduous NDVI

Median NDVI for each year
TDA-SVM Result with replaced image

Change map 09/02/1999 – 10/07/2006

Change map 09/02/1999 – 08/28/2006

Legend
change_map_1990_2000_MLC.tif
Value
Unclassified
Forest to Forest
Forest to Non Forest
Non Forest to Forest
Non Forest to Non Forest
FCC Challenges: Solutions

• Terrain Illumination Correction:
  – Bin Tan, Jeff Masek, et. al.
Mapping Forest Changes in Mountain Area

Path 46, Row 32

1989-09-03

2002-10-01

SVM Result

- Deforest
- Regrowth
- Forest
- Non Forest
Illumination Condition (IL)

\[ IL = \cos Z \cdot \cos S + \sin Z \cdot \sin S \cdot \cos(\phi_z - \phi_s) \]

Z: the solar zenith angle,
\( \Phi_z \): the solar azimuth angle,
S: the slope angle,
\( \Phi_s \): is the aspect angle of the incline surface.
Rotation Model:

\[ L_H(\lambda) = L_i(\lambda) - (a \times IL + b) \]

Where \( a \) and \( b \) are from regression.
Corrected Reflectance

TOA-Original

TOA-Corrected

TOC-Original

TOC-Corrected
Terrain Illumination: Synopsis

- Works well with GLSDEM at 30m over US
  - 90m DEM globally starts producing artifacts
- Working towards integrating ASTER GDEM globally at 30m
FCC Challenges: Solutions

• Commission errors:
  • Large crop regions
  • Semi arid/spare forests
FCC Challenges: Solutions

Problem

• TDA-SVM can detect most changes, but it has two main problems:
  – Too much false changes in sparse forest and major crop regions
  – Underestimate forest in sparse forest region

Solutions

• Create additional, correct training samples in some false change area, then rerun SVM to map change
  – Use MODIS to identify known false changes
  – Determine whether the false change pixels are forest or not
Overall Concept and Assumption

- MODIS NDVI trend by different states follows distinctive patterns.
- Detected changes (size > a MODIS pixel) can be validated using MODIS time series data.
- Once change pixels are validated, it can be added to existing training data.
MODIS NDVI for the area miss-identified by TDA

- NDVI trend of Persistent Forest confused as deforestation
- NDVI trend of Persistent Non-Forest confused as regrowth
- NDVI trend of Persistent Forest confused as regrowth
- NDVI trend of deforestation confused as regrowth
Training Data Update

90% (for example) of pixel is change
Aggregated to 1km

Compared with MODIS NDVI

Actual Change?

Add Change pixels to Training data.
Results

Path 176 Row 54
Results

Path 230 Row 77
Results

Path 29 Row 45
Results

Path 229 Row 79
FCC Challenges: Solutions

• Problem:
  – Crop pixels present similar spectral signatures as tree pixels during peak phenological seasons, causing misclassifications in single-date Landsat image as well as false forest changes in two-date images.
Solution:

- Given the variability of crop types and phenology at local to global scales, reliable external land cover information is needed to assist Landsat classification and change detection.
- Converging Landsat surface reflectance, MODIS VCF and MODIS cropland probability product, automatically select confident tree and crop pixels as training for SVM.
Results

Path 15 Row 32
Results

Path 224 Row 78
MODIS VCF FCC 2000 - 2005
Lessons Learned

- Mission creep
- Be ready to take on “known and unknown unknowns” issues
  - Calibration issues; issues with data in general
  - Phenological issues
- Multiple iterations of data processing
- Benchmarking
- Scene based solution don’t work, make changes to your algorithm and process globally.
- Data volume
- End-to-end process has been challenging to automate.
- Really should be using multi temporal data within a year to define what is and is not forest.
Other data sources e.g. HJ data

2009-06-30

2011-06-08

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Questions

Please visit the GLCF at www.landcover.org