Multi-sensor imaging of tree and water cover time-series at continental to global scales

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Objectives: algorithms

- Multi-sensor ("-agnostic") estimation of land cover
  - tree-canopy (percent)
  - water (binary)
- Landsat-5,-7 (Global Land Survey)
- Sentinel-1, -2

Targets: land-cover datasets

- Percent tree-canopy cover & binary water cover
  - Resolution: annual, 30-m
  - Extent:
    - North and South America from 2010 - 2015
Algorithm - estimation

\[ p(c_i) \overset{\text{def}}{=} N(\hat{c}_i, \sigma^2) \]

\[ c_i = f(X; \beta) + \epsilon_i, \]

\[ \sigma_\epsilon = \sqrt{\frac{\sum_i(c_i - \hat{c}_i)^2}{n - 1}}. \]
Global, pixel-level estimates of cover and uncertainty.

\[ c_i = f(X; \beta) + \varepsilon_i, \]

A model for the distribution of all possible states of tree cover, given the best available imagery.

\[ \sigma_e = \sqrt{\frac{\sum (c_i - \hat{c}_i)^2}{n - 1}} \]
Compositing output estimates

- Based on uncertainty layers
  - Principle of Maximum Likelihood: Take the estimate of cover with the lowest uncertainty
  - Clean cloud, shadow, snow
  - Uncertainty drops with increasing image-density
Forest gain & loss

\[ p(p) = p(F_1 \times p(F_2)) \]

\[ p(N_N) = 1 - p(F_1 \times 1 - p(F_2)) \]

\[ p(F_N) = 1 - p(F_1 \times p(F_2)) \]

\[ p(F_L) = p(F_1 \times 1 - p(F_2)) \]

NDVI
Canopy gain/loss (e.g., degradation)


Tree Cover and Loss (Tsaagan-Uur, Mongolia)
Multi-sensor fusion of Landsat and Sentinel-2

• Sample of 5 sites
  • North & South America
  • all forest biomes

• Data
  • Previous: GLS Landsat -5, -7
    • Global Land Survey (GLS)
  • New: HLS S30
    • 9581 Landsat-8
    • 3177 Sentinel-2
    • 12758 total
Optical-SAR fusion

• Estimate tree canopy cover
• Fill gaps (e.g., clouds) in optical estimates
• Discriminate natural forests from plantations

• Sentinel C-band backscatter & ratios
• UAVSAR L-band entropy

• Solely C-band models unlikely to discriminate forest types—need to incorporate with optical
• Possible L-band only model

Pinto et al. in prep.
China's largest freshwater lake three times the size of London dries up due to drought

- New pictures show parts of the Poyang Lake in China's Jiangxi province turning into a huge grassland
- The lake was once 4,500 square kilometres (1,737 square miles), three times the size of Greater London
- Water in Poyang recedes every winter but this year the dry season arrived early due to a shortage of rainfall

By JULIAN LUK FOR MAILONLINE
PUBLISHED: 06:37 EDT, 4 November 2016 | UPDATED: 10:53 EDT, 4 November 2016
From masking water to estimating inundation frequency

Aral Sea’s Eastern Basin Is Dry for First Time in 600 Years

August 25, 2000  August 19, 2014
Calibration & validation

Reference:
- Lidar
- High-res
- Drone?

Metrics:

\[
RMSE = \frac{\sum_{i=1}^{n} \sqrt{(M_i - R_i)^2}}{n}
\]

\[
RMSD = \sqrt{RMSD_s^2 + RMSD_u^2}
\]

\[
RMSE_s = \sqrt{\frac{\sum_{i=1}^{n} (M_i - R_i)^2}{n}}
\]

\[
RMSE_u = \sqrt{\frac{\sum_{i=1}^{n} (M_i - \hat{M}_i)^2}{n}}
\]
Progress

Data:

✓ tree-canopy cover (%)
  • North- and South-America coverage at 30-m, annual resolution from 2010 – 2015
  • Per-pixel estimates of uncertainty
  • Ecoregional, lidar-based validation

✓ Inundation frequency (p(water))
  • North- and South-America coverage at 30-m, annual resolution from 2010 – 2015

Algorithms:

• Estimation
  ✓ single-image to “full-stack”
  ✓ Landsat or Sentinel-2, Landsat and Sentinel-2

• Validation & calibration
  ✓ Validation of tree-canopy cover based on high-resolution imagery
  ✓ Lidar-based (linear) calibration of tree-canopy cover
Application & validation
Mapping the taiga-tundra ecotone

• Motive
  • Global indicator of biosphere response to climate change

• Challenges
  • Ecology
    • Climate: temperature, precipitation
    • Soil: depth, structure
    • Biology: dispersal, competition
  • Remote sensing
    • Short, sparse canopies
    • Snow & water cover
    • Short viewing seasons & shallow illumination angles

• Ecoregional calibration
  • Lidar & high-resolution optical
  • Empirical, linear

• Results
  • Removed saturation at >80% canopy cover
  • Reduced uncertainty (RMSE) by ~ 50%
  • More sensitive to cover of trees defined by > 2 m height
Philippine National Forest Monitoring System

- **Sponsor:** USAID/USFS
- **Objectives**
  - Nationally calibrated forest/nonforest dataset
  - Establish forest reference emission level (FREL)
  - Build capacity of national forestry & mapping agencies
- **Partners**
  - National
    - Forest Management Bureau
    - NAMRIA
  - International/Implementing
    - B-WISER
Deforestation & conflict in Myanmar

- Coupling of forest clearing & civil conflict?
- Spatially complex dynamics
  - Small patches
  - Regional variation in change-rate & acceleration
- In-country partners
  - Potential for calibration
- Data specs
  - Thematic: Tree-canopy cover, forest loss
  - Spatial: national extent at 30-m resolution
  - Temporal: annual frequency from 2000 – 2018
  - Accuracy: locally calibrated (drone)

- Progress

- Improvement
  - Filled gaps
  - Increased precision

RMSE (% TCC)

- 0-15%
- 15-30%
- 30-50%
- 50-100%

- TCC (GLS 2010)
- TCC 2010 (new version)
Milestones & products

- North- and South-America coverage at 30-m, annual resolution from 2010 – 2015
- Lidar-based calibration & validation of tree-canopy cover
- SAR discrimination of natural forest vs. plantation (oil palm)
- Algorithms developed & ready for HLS
  - Estimation
  - Change detection
    - Forest loss & degradation
  - Time-series
    - Disturbance & regrowth history
    - Stand age

- Data available at
  - Visualization: [www.terraPulse.com/terraView](http://www.terraPulse.com/terraView)
  - Download: [www.landcover.org/treeCover](http://www.landcover.org/treeCover)
ESA GLOBBIOMASS

- Series of international meetings
- Landsat-based tree-canopy cover distributed to GLOBBIOMASS
- GLOBBIOMASS using tree-canopy cover as a predictor of higher-level products
- GLOBBIOMASS funded for second round
Polar-ICE data stories

• Outreaching Arctic science to elementary schools
• Course modules built for science classes
• Science teachers instructed on ecology & Earth observation
The cloud/shadow masks have significantly improved in version 1.3, but commission and omission errors were found for cloud, shadow, and water.

The HDF files of L30 and S30 v1.3 are not compatible with HDF-EOS.