Pathfinding near real time moderate resolution land surface monitoring: looking forward to an operational Landsat 9/10 Sentinel 2A/2B era

David P. Roy, Lin Yan, Hankui K. Zhang
Geospatial Sciences Center of Excellence,
Wecota Hall, South Dakota State University Brookings, SD 57007

Haiyan Huang, Zhongbin Li, Alexey Egorov

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Li, J and Roy, D.P. 2017
Task #1  Develop Sentinel-2 ARD comparable to the Landsat ARD

Task #2  Undertake quality assessment and characterization of the consistency of the Landsat & Sentinel-2 ARD

Task #3  Investigate the utility of the Landsat & Sentinel-2 ARD to develop annual land cover products

Task #4  Investigate the utility of the Landsat & Sentinel-2 ARD to develop timely land cover mapping within the growing season

Task #5  Assess the expansion of tasks #1-4 to global scale

Task #6  Provide feedback on planned Landsat-10 capabilities
Task #1 develop Landsat and Sentinel-2 processing, involving development of Sentinel-2 ARD comparable to the Landsat ARD, with reflectance correction to nadir BRDF-adjusted reflectance (NBAR).
Landsat-8 ARD

January 1 – 7 2018

72 CONUS ARD tiles
(5000 × 5000 30 m pixels each)

True color TOA reflectance
2806 × 2480 0.51 km browse pixels
True color TOA reflectance
2806 × 2480 0.51 km browse pixels

Sentinel-2A ARD

January 1 – 7 2018

72 CONUS ARD tiles
(5000 × 5000 30 m pixels each)
Sentinel-2B ARD

January 1 – 7 2018

72 CONUS ARD tiles
(5000 × 5000 30 m pixels each)

True color TOA reflectance
2806 × 2480 0.51 km browse pixels
7 x 7 WELD tiles
1200 x 1200 km
MODIS tile h20v10

Sentinel-2A
V2.3.1
Sen2Cor
surface reflectance

week 30
Jul. 22-28 2016
Sentinel-2A
V3.5.3
LaSRC
surface reflectance
week 30
Jul. 22-28 2016

7 x 7 WELD tiles
1200 x 1200 km
MODIS tile h20v10
Sentinel-2A
V3.5.5
LaSRC
surface reflectance
week 30
Jul. 22-28 2016

7 x 7 WELD tiles
1200 x 1200 km
MODIS tile h20v10
Landsat 8 <-> Sentinel 2
misregistration characterization, UTM 35

\[ \mu = 2.761, \sigma = 1.075, \text{max} = 4.990 \text{ (10m pixels)} \ (4,574 \text{ matched image pairs}) \]
Landsat 8 <-> Sentinel 2 misregistration characterization, UTM 35 after partial-orbit based registration

\[ \mu = 0.161, \sigma = 0.076, \text{max} = 0.624 \text{ (10m pixels) (4,574 matched image pairs)} \]

Yan et al. 2018
Landsat 8 Collection 1
June 3 2016
Copperbelt Province, Zambia
500 × 500 10 m pixels, NIR
Original Registered

Sentinel 2A
June 12 2016

Copperbelt Provence, Zambia
500 × 500 10 m pixels, NIR
Sentinel 2A
June 22 2016

Copperbelt Provence, Zambia

500 × 500 10 m pixels, NIR
Original Registered

Sentinel 2A
July 2 2016

Copperbelt Provence, Zambia

500 × 500 10 m pixels, NIR
Original Registered

Landsat 8 Collection 1
July 5 2016

Copperbelt Provence, Zambia
500 × 500 10 m pixels, NIR
Landsat has non-negligible BRDF

1.3 million pairs of L5 & L7 observations extracted from overlap
Landsat has non-negligible BRDF

Landsat 5 (blue)
Landsat 7 (red)

1.3 million pairs of L5 & L7 observations extracted from overlap

Landsat NBAR - BRDF corrected $\rho$ using fixed global MODIS coefficients

Sentinel-2 has non-negligible BRDF

Sentinel-2 has non-negligible BRDF

Task #2 Undertake quality assessment and characterization of the consistency of the Landsat ARD & Sentinel-2 ARD
Landsat-8 OLI (filled circles •) and Sentinel-2A (open circles ○) atmospherically corrected NBAR

A woody savanna pixel location in the 2016 dry season over Zambia (74 days)
Landsat-8 OLI (filled circles ●) and adjusted Sentinel-2A (open circles ○) atmospherically corrected NBAR

A woody savanna pixel location in the 2016 dry season over Zambia (74 days)

\[ y = 0.9890 \times \]
\[ n = 65380145 \]
\[ \text{RMSD} = 0.0146 \]
Task #3 Investigate the utility of the Landsat and Sentinel-2 ARD to develop annual land cover products
30m land cover classification: random forest classification of Landsat multi-temporal metrics derived from 3 years of Global WELD MODIS (IGBP) class legend

0. Water
1. Evergreen needleleaf forest
2. Evergreen broadleaf forest
3. Deciduous needleleaf forest
4. Deciduous broadleaf forest
5. Mixed forest
6. Closed shrublands
7. Open shrublands
8. Woody savannas
9. Savannas
10. Grasslands
11. Permanent wetlands
12. Croplands
13. Urban and built-up
14. Cropland/natural vegetation
15. Snow and ice
16. Barren or sparsely vegetated

Landsat CONUS ARD
30 m % tree cover estimation
Regression tree estimation of Landsat multi-temporal metrics derived from 5-years of ARD.

Egorov, A.V., Roy, D.P., Zhang, H.K., Hansen, M.C., Kommareddy, A., 2018, Demonstration of percent tree cover classification using Landsat analysis ready data (ARD) and sensitivity analysis with respect to Landsat ARD processing level, Remote Sensing, 10(2), 209.

First ever paper using Landsat ARD??? 😮
Egorov et al 2018, Demonstration of Percent Tree Cover Mapping Using #Landsat Analysis Ready Data (ARD) and Sensitivity with Respect to Landsat ARD Processing Level. #lidar @USGSLandsat
Task #4 Investigate the utility of the Landsat and Sentinel-2 ARD to develop timely land cover mapping within the growing season
Seward, Nebraska
400 × 400 30m pixels
USDA 2010 Crop Data Layer (CDL)
corn, soybean, winter wheat, alfalfa,
grass, forest, urban/developed

Harmonic model fitted to one year of 2010
Landsat-5 and -7 WELD data for each 30 m pixel location

NDVI

soybean

winter wheat

DOY
Harmonic time series model fitting challenging within a year ...

Seward, Nebraska
400 × 400 30m pixels
USDA 2010 Crop Data Layer (CDL)
corn, soybean, winter wheat, alfalfa,
good, forest, urban/developed

Harmonic model fitted to one year of 2010
Landsat-5 and -7 WELD data for each 30 m pixel location

NDVI

soybean

winter wheat

DOY
2009 CDL

USDA 2010 Crop Data Layer (CDL)
corn, soybean, winter wheat, alfalfa, grass, forest, urban/developed

Harmonic time series model fitting challenging inter-annual change ...
Harmonic time series model fitting challenging inter-annual change ...

USDA 2010 Crop Data Layer (CDL)
corn, soybean, winter wheat, alfalfa, grass, forest, urban/developed
Yan, L. and Roy D.P., Robust large-area gap filling of Landsat reflectance time series by spectral-angle-mapper based spatio-temporal similarity (SAMSTS), Remote Sensing of Environment.
Yan, L. and Roy D.P., Robust large-area gap filling of Landsat reflectance time series by spectral-angle-mapper based spatio-temporal similarity (SAMSTS), Remote Sensing of Environment.
Harmonic-model gap filled image

5-band RMSD
Mean = 0.023
SAMSTS gap filled image

5-band RMSD
Mean = 0.018
Task #5 Assess the expansion of tasks #1-4 to global scale, including making recommendations concerning the development of a global ARD
Global monthly Landsat data

Geographic Lat./Long. projection

Each 1.35km true color browse pixel
generated from 45 x 45 30m Landsat 7 ETM+ pixels
Global monthly Landsat data

Equal area sinusoidal projection

Each 1.35km true color browse pixel
generated from 45 x 45 30m Landsat 7 ETM+ pixels
Global WELD NEX V3.0 Annual 2000 30 m product
124,948 scenes (39,542 Landsat 5 & 85,404 Landsat 7)

Surface reflectance
nadir BRDF adjusted reflectance (NBAR)
Global WELD NEX V3.0 Annual 2000 30 m product
124,948 scenes (39,542 Landsat 5 & 85,404 Landsat 7)

Number of observations

MODIS sinusoidal projection
29,652 x 14,826 1.35km browse pixels
Global WELD NEX V3.0 Annual 2010 30 m product
124,433 scenes (45,711 Landsat 5 & 78,722 Landsat 7)

Number of observations

MODIS sinusoidal projection
29,652 x 14,826 1.35km browse pixels
Global WELD NEX V3.0 Annual 2010 30 m product
124,433 scenes (45,711 Landsat 5 & 78,722 Landsat 7)

Surface reflectance
nadir BRDF adjusted reflectance (NBAR)
Task #1 Develop Sentinel-2 ARD comparable to the Landsat ARD

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Task #5 Assess the expansion of tasks #1-4 to global scale - global ARD

Task #6 Through these integrative activities make informed recommendations for and provide feedback on planned Landsat-10 observational capabilities
Future: Evolution Towards Integrated Observations

Today: “Stovepiped” Observing Systems

Tomorrow: Distributed Space Systems for Integrated Observations

Looking forward to an operational Landsat Sentinel 2 era!