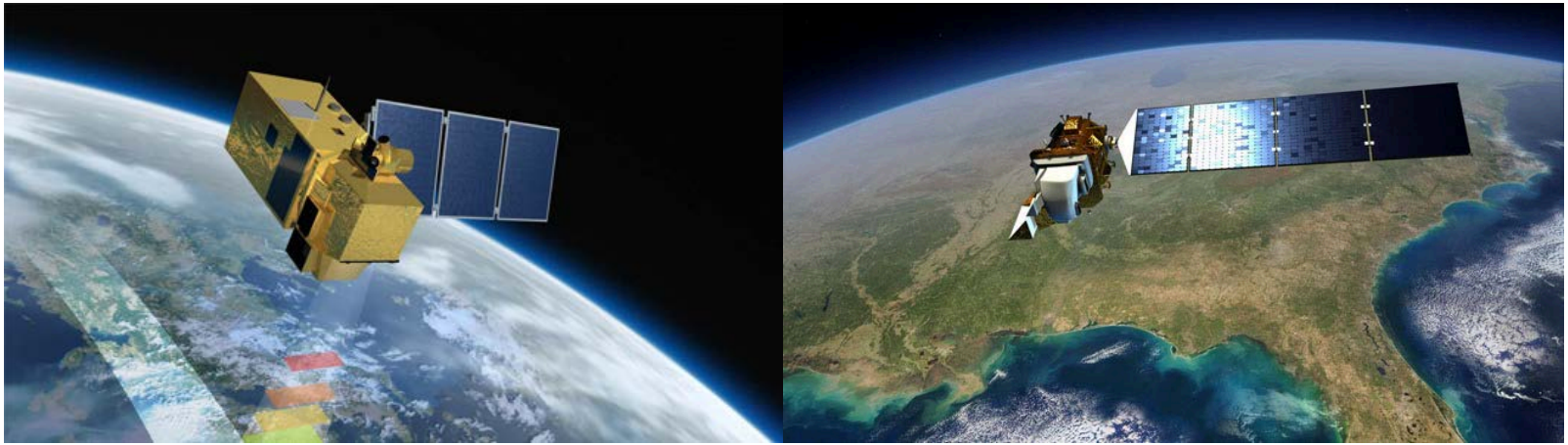
Multi-Source Land Imaging (MuSLI) Review

Jeffrey Masek, NASA GSFC
April 5, 2018



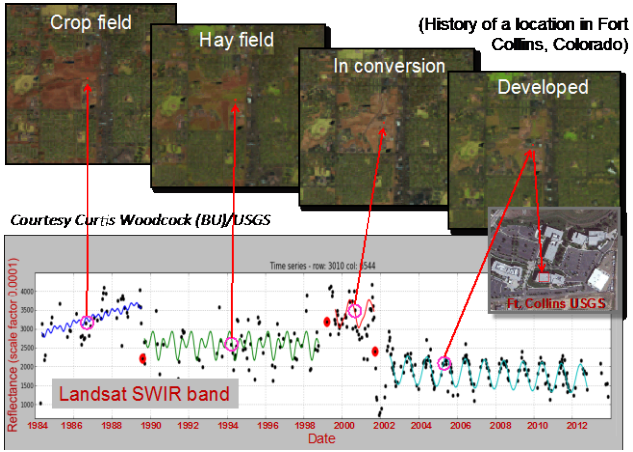
Outline

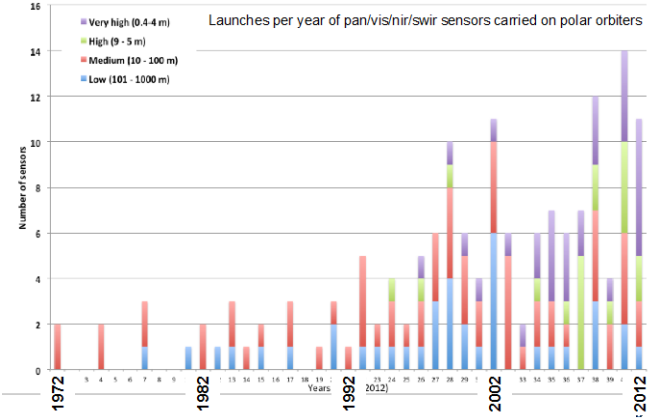
- MuSLI In Review
- Supporting Activities
- Updates from ESA
- Landsat Science Team (Chris Crawford, USGS)

Context

- Time series observations increasingly central to land monitoring
  - Near-daily optical & radar data needed key for “fast” ecological and land use dynamics (agriculture, vegetation phenology, disturbance, etc…)
  - Also needed to secure interannual data in cloudy areas (e.g. REDD+)
  - Desire for a “Daily MODIS” capability

- Harnessing the diversity of international remote sensing systems can provide this capability, at a fraction of the cost of a new mission





NASA MuSLI Program

- NASA Multi-Source Land Imaging (MuSLI) Team is a research program designed to advance use of multi-source remote sensing data for land monitoring
  - Solicited 2014 through NASA Land Cover/Land Use Change Program
  - Three-year projects (2015-17)
  - Re-competed in 2017 for second three year cycle

- Objectives:
  - **Develop algorithms and prototype products** that make use of multiple satellite sources & time series approaches
    - *Focus on Landsat and Sentinel-1 & 2*
    - *Focus on evolving continental-scale products analogous to what is available from MODIS, but at moderate resolution (<100m)*
  - Understand challenges associated with algorithms & processing streams that incorporate multiple satellite systems
  - Develop stronger community of practice among US and international (especially EU) researchers

2014-17 NASA MuSLI Teams

Project Title	PI	International Collaborators
Multisource Imaging of Seasonal Dynamics in Land Surface Phenology	Friedl/BU	Eklundh / Lund
Integrating Landsat 7, 8 and Sentinel 2 Data in Improving Crop Type Identification and Area Estimation	Hansen/UMD	Defourny / Louvain
Towards Near Daily Monitoring of Inundated Areas Over North America Through Multi-Source Fusion of Optical and Radar Data	Lang / UMD	Creed / Western
Prototyping a Landsat-8/Sentinel-2 Global Burned Area Product	Roy / SDSU	Chuvieco / Alcala; Tansey / Leicester
Operational Algorithms and Products for Near Real Time Maps of Rice Extent and Rice Crop Growth Stage Using Multi-Source Remote Sensing	Salas / Applied Geosystems	Hoekman / Wageningen; Le Toan / CESBIO
Multi-Source Imaging of Infrastructure and Urban Growth Using Landsat, Sentinel and SRTM	Small / Columbia U	Esch / DLR
Multi-Source Imaging of Time-Serial Tree and Water Cover at Continental to Global Scales	Townshend / UMD	Schmullius /Jena

2017 MuSLI Solicitation

- 2017 solicitation was divided into two parts:
  - Type 1: Full-scale continental/global scale products
    - Projects must have demonstrated algorithms, and approach to product validation documented
    - Processing costs supported by NASA
  - Type 2: Prototype products at regional scales

- Both Type 1 & 2 proposals needed to demonstrate
  - Community need for the information products proposed
  - Feasibility of producing products
  - Necessity of using multiple sources of data
  - International collaboration

2018-2020 MuSLI Projects

Mark Friedl (Boston U)	An Operational Multisource Land Surface Phenology Product from Landsat and Sentinel 2
David Roy (South Dakota State U.)	Africa Burned Area Product Generation, Quality Assessment and Validation - Demonstrating a Multi-Source Land Imaging (MuSLI) Landsat-8 Sentinel-2 Capability
Crystal Schaaf (U. Mass - Boston)	Circumpolar Albedo of Northern Lands from Landsat-8 and Sentinel-2
Martha Anderson (USDA)	Characterizing Field-Scale Water Use, Phenology and Productivity in Agricultural Landscapes Using Multi-Sensor Data Fusion
Petya Campbell (U. Maryland - Baltimore County)	Prototyping MuSLI canopy Chlorophyll Content for Assessment of Vegetation Function and Productivity
Glynn Hulley (JPL)	A High Spatio-Temporal Resolution Land Surface Temperature (LST) Product for Urban Environments
Volker Radeloff (U. Wisconsin)	Monitoring Abandoned Agriculture, Fallow Fields, and Grasslands with Landsat and Sentinel-2
Sergii Skakun (U. Maryland - College Park)	Crop Yield Assessment and Mapping by a Combined use of Landsat-8, Sentinel-2 and Sentinel-1 Images

Type 1: Continental-scale products

Type 2: Regional-scale prototypes

7

MuSLI Accomplishments

- Projects successfully developed new and improved land products via multi-source data sources
- US researchers gained knowledge and experience with Copernicus sensors and data sets
- MuSLI team was able to provide feedback to ESA on data quality and usability issues
  - Geolocation errors
  - Product format (filenames, granule organization, etc)
  - Importance of reprocessing & collections
- MuSLI team provided feedback to USGS and NASA on data mirroring of Sentinel-2/1 archives
- Some movement toward increased collaboration with EU colleagues (e.g. ESA Living Planet)

MuSLI Challenges

- Projects had to work through numerous technical challenges w/ S1 and S2 data (we were on the “bleeding edge” with the new sensors)
  - Geolocation of S2 WRT Landsat (and adjacent orbit S2)
  - Sen2Cor atmospheric correction, poor cloud mask options
  - Lack of Sentinel-1 tiling system
  - Initial data access via ESA SciHub (now Copernicus Open Access)
  - Sentinel acquisition coverage ramped up more slowly than anticipated, limiting data availability outside Europe+Africa
- US-EU collaboration was never as strong as hoped
- Not all groups pursued integration of international data with single-minded determination

Issues in Working with Sentinel-2

- Geolocation
  - Landsat vs. S2 - see Storey et al (2016)
  - S2 vs S2 for adjacent orbits - yaw processing issue corrected in June 2016
- S2a bandpasses for B01, B02, B08 incorrect as originally published; users should use S2b bandpasses for these bands
- Cloud masking problematic without TIR band
  - Multiple cloud/shadow approaches but no clear “winner” at the moment
- S2 MGRS UTM tiling system can be difficult (overlap of 10km at edges)
- Lack of reprocessing for S2 data
  - No adoption of “Collection” concept with fixed algorithms
  - Entire dataset should be reprocessed when Global Reference Image (GRI) established, but date keeps slipping

Supporting Activities

- Radiometric cross calibration
- Harmonized Landsat/Sentinel-2 (HLS) Product
- Sentinel-2 Cloud Masking

L8/S2 Radiometric Cross-calibration

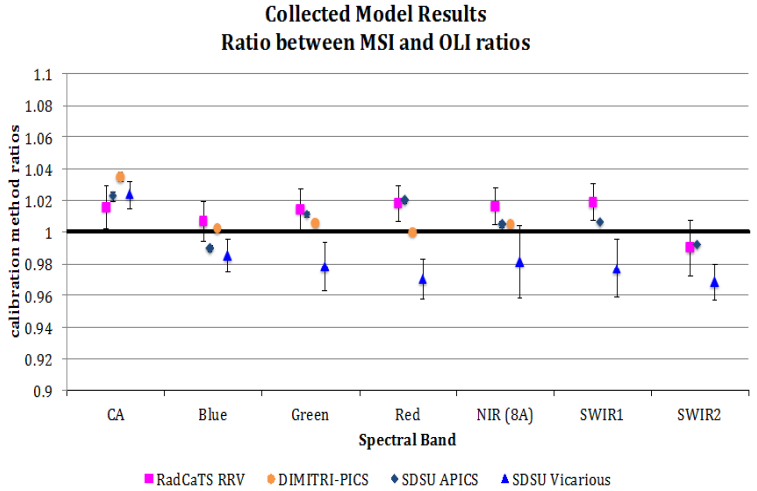
Since Sentinel-2 launch, NASA, USGS, and ESA teams have compared coincident acquisitions with L8 over pseudo-invariant sites & calibration targets

Accounting for bandpass differences (e.g. using Hyperion spectra), absolute differences between the TOA reflectances **are ~2-3%,** which is within the uncertainty of the individual systems.

- *some indication of greater uncertainty for C/A band*
- *see: Barsi, J., Alhammoud, B., Czapla-Myers, J., Gascon, F., Haque, MH., Maewmanee, M., Leigh, L., Markham, B., 2018. Sentinel-2A MSI and Landsat-8 OLI Radiometric Cross Comparison. European Journal of Remote Sensing, in review.*

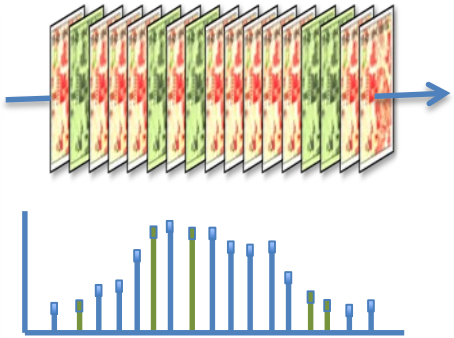
Dennis Helder (SDSU) organized joint workshop at Pecora-20 to review results and make recommendations for future activities:

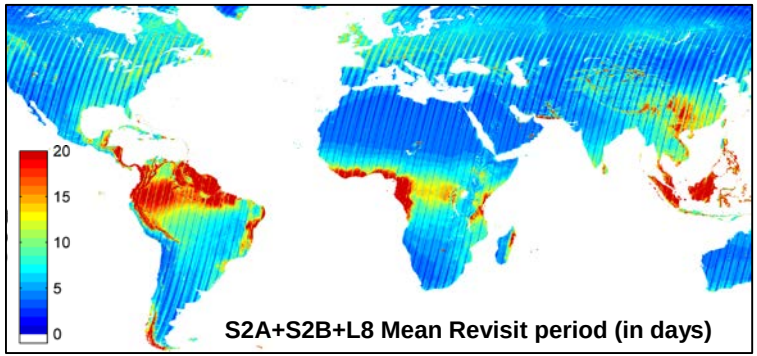
- *Improved communication between ESA & US teams*
- *Improved communication with user community*
- *Standardization of analysis techniques*
- *Recommendation for ESA to move to Collection-based data processing*
- *Greater emphasis on validation of Level-2 products*

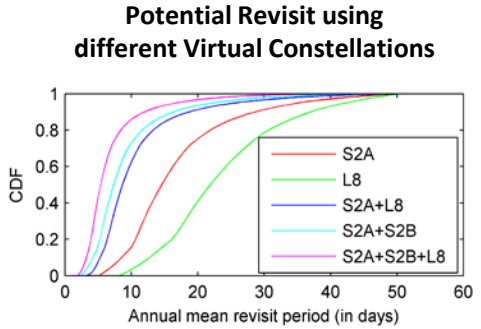


Harmonized Landsat Sentinel-2 (HLS) Project

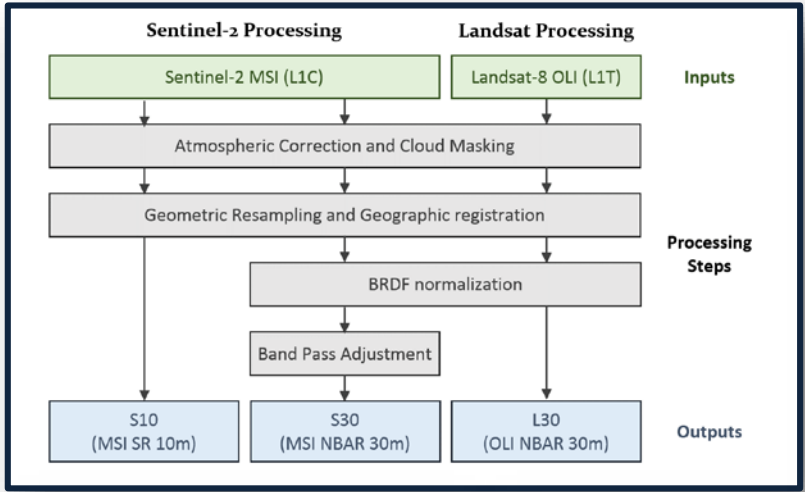
- Merging Sentinel-2 and Landsat data streams can provide 2-3 day global coverage
- **Goal is "seamless" near-daily 30m surface reflectance record** including atmospheric corrections, spectral and BRDF adjustments, regridding
- Project initiated in 2013 as collaboration among NASA GSFC, UMD, NASA Ames
- Prototype for a multi-sensor Analysis Ready Data product



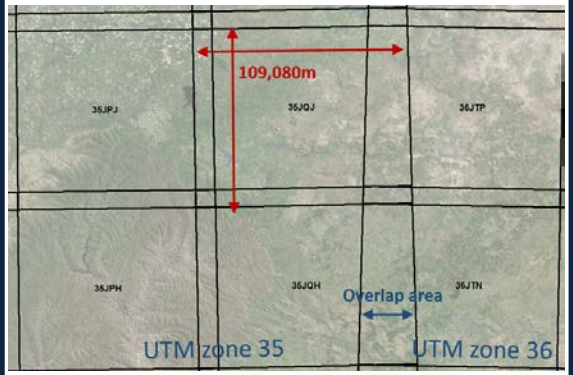




HLS Main specs and Algorithm Flow



All 3 products are aligned on the MGRS S2 Tiles system following UTM zones



S10 (from Sentinel-2)
Spatial: 10m, 20m, 60m
Spectral Bands: All MSI
NBAR: No

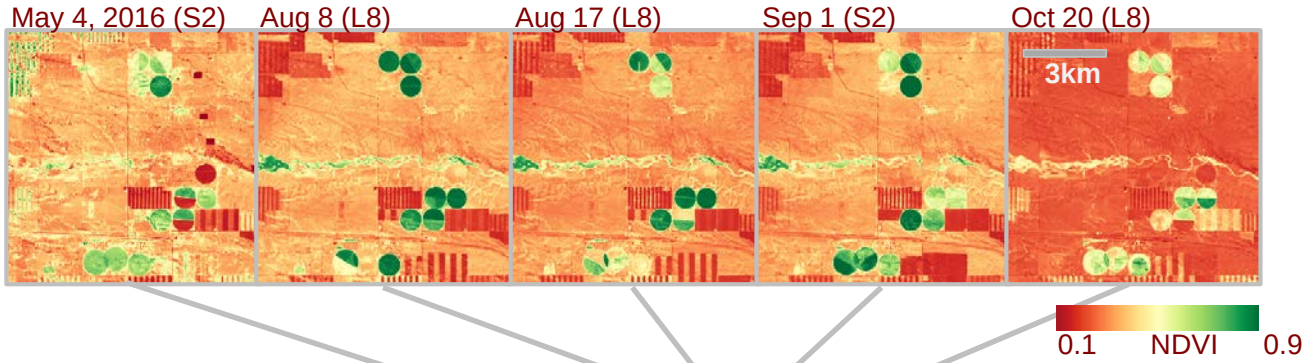
S30 (from Sentinel-2)
Spatial: 30m
Spectral Bands: OLI-like + MSI Red Edge
NBAR: Yes

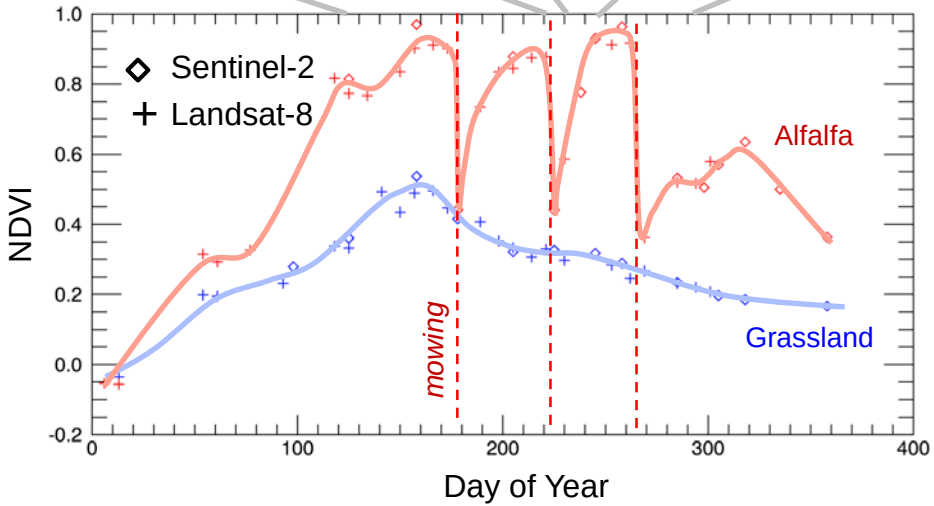
L30 (from Landsat 8)
Spatial: 30m
Spectral Bands: All OLI
NBAR: Yes

Atmospheric Correction	**LaSRC/6S approach (image-based aerosol)**	**Vermote et al. (2016)**
BRDF normalization	**C-factor technique with the global constant coefficients**	**Roy et al. (2016)**
Spectral bandpass	**Linear regression using global training set from EO-1 Hyperion**	**Claverie et al., (in review)**
Cloud/shadow mask	**Landsat 8: output from LaSRC; Sentinel-2: Boston University Fmask algorithm**	**Vermote et al. (2016); Zhu et al. (2015)**
Geographic registration	**AROP: automated registration and orthorectification package**	**Gao et al. (2009)**

Harmonized Landsat / Sentinel-2 Products

Laramie County, WY



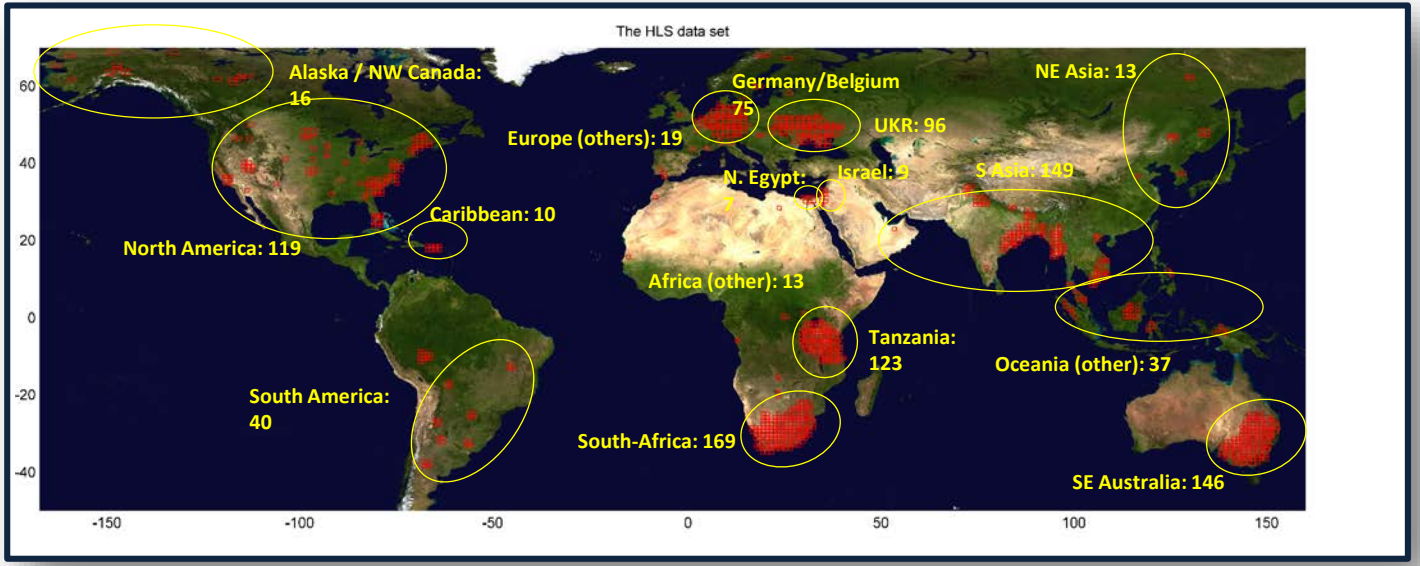


Seasonal phenology (greening) for natural grassland (blue line) and irrigated alfalfa fields (red line) near Cheyenne Wyoming observed from Harmonized Landsat/Sentinel-2 data products. The high temporal density of observations allows individual mowing events to be detected within alfalfa fields. HLS Products available from https://hls.gsfc.nasa.gov

HLS [v1.3] data set extend

- ~100Test sites
- ~1000 MGRS tiles
- >10 million sq. km2 (~7% of global land area)

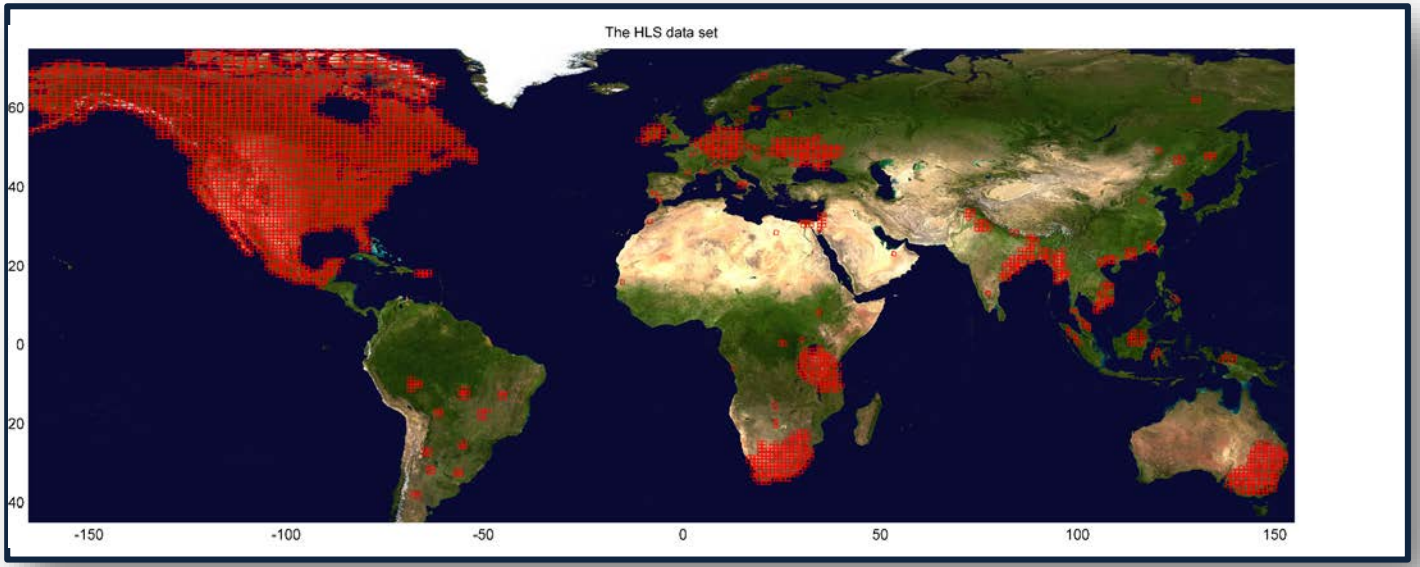
- Landsat-8 data set: 200k products
  From Mar-2013 to May-2017
- Sentinel-2 data set: 90k products
  From Oct-2015 to May-2017



HLS [v1.4] data set extent

- 105 Test sites
- 3904 MGRS tiles
- >37 million sq. km2 (~25% of global land area)

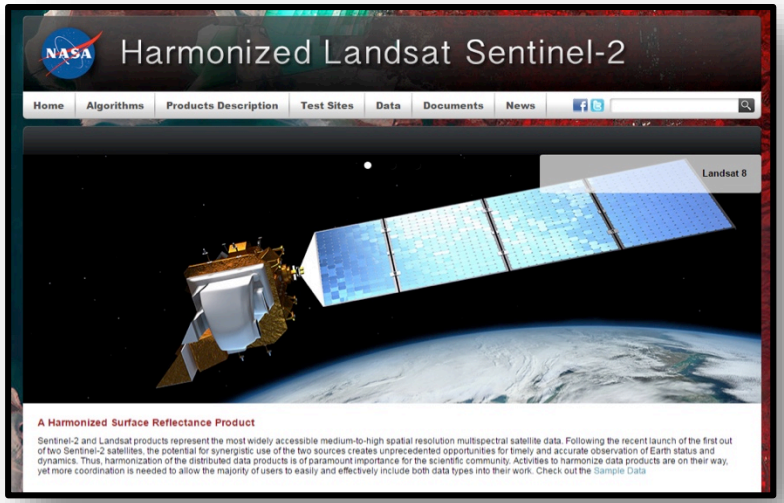
- Landsat-8 data set: 1,100k products From Mar-2013 to Present (135 TB)
- Sentinel-2 data set: 420k products From Jun-2015 to Present (60 + 274 TB)
- Keep-up processing (<7 day latency)
- Available this Spring



HLS Websites and Public Interface

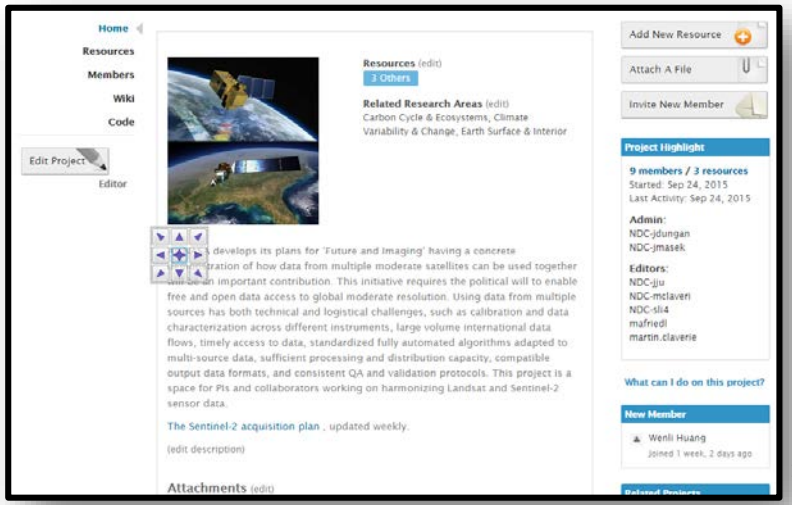
- HLS website

- https://hls.gsfc.nasa.gov
- Public access
- Sample data available (via FTP)
- Algorithm & Product descriptions



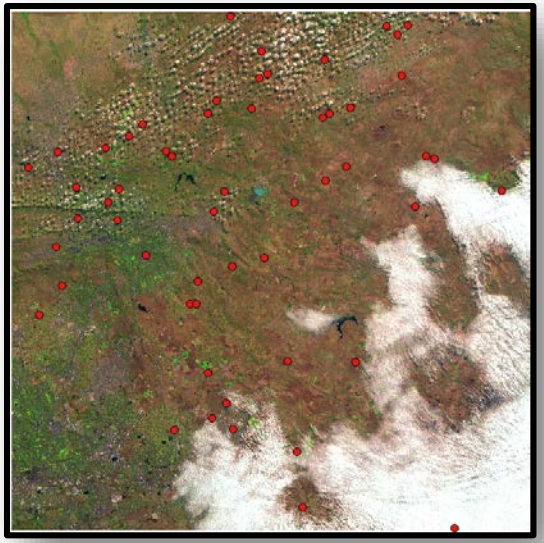
- NEX project page

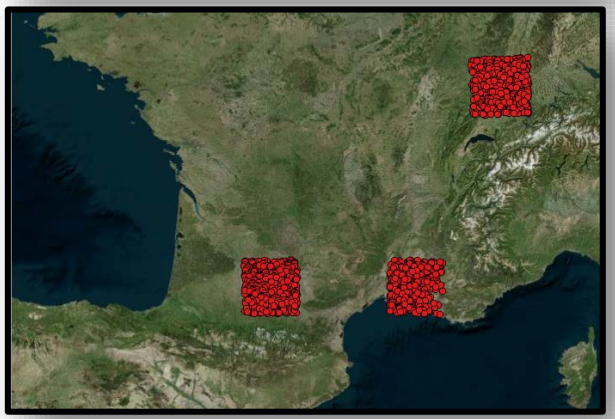
- https://nex.nasa.gov/nex/projects/1371
- Registered user access
- All HLS data available
- Documents (slides, user guides)



Cloud Mask Evaluation

- Boston University/C. Woodcock conducting evaluation of S2 cloud masking algorithms
- Random sample from 28 Sentinel-2 images selected from 6 study sites
  - Primary samples were selected on disagreement area
  - Additional samples selected from agreement area
- Five Cloud Mask processors: LaSRC, MAJA, Sen2Cor, Fmask and Tmask





Courtesy of C. Woodcock group (Boston University)

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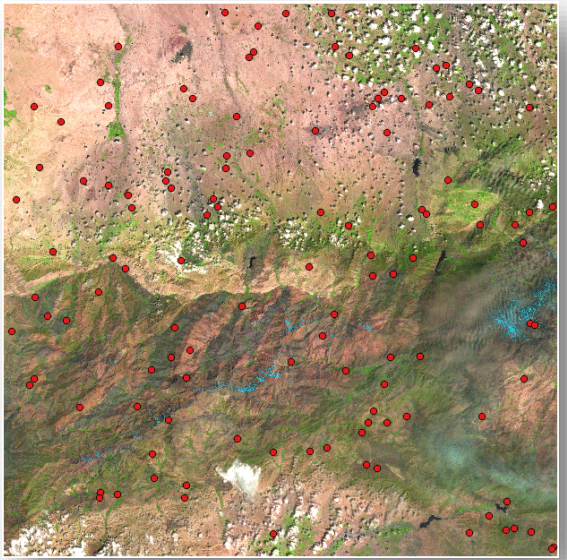
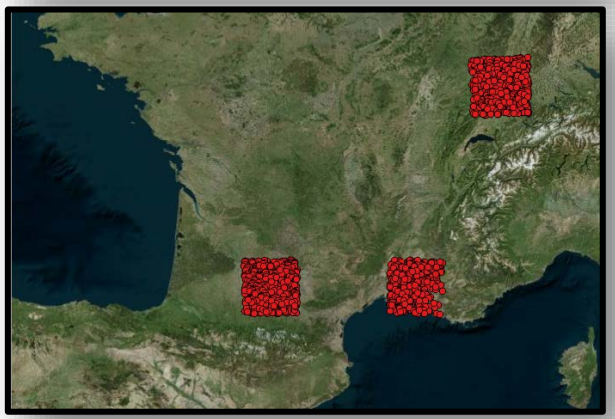




Courtesy of C. Woodcock group (Boston University)

Cloud Mask Evaluation

LaSRC	Clear	Shadow	Cloud
Clear	615	296	139
Shadow	84	215	77
Cloud	242	112	901

MAJA	Clear	Shadow	Cloud
Clear	439	37	207
Shadow	265	340	148
Cloud	237	246	762

Sen2Cor	Clear	Shadow	Cloud
Clear	899	435	683
Shadow	26	179	35
Cloud	16	9	399

	cloud omission	cloud commission	overall scores
MAJA	32%	39%	57%
LaSRC	19%	28%	65%
Sen2Cor	64%	6%	55%
Fmask	32%	19%	69%
Tmask	32%	21%	60%

Tmask	Clear	Shadow	Cloud
Clear	613	47	355
Shadow	238	547	304
Cloud	90	29	458

Fmask	Clear	Shadow	Cloud
Clear	748	195	228
Shadow	101	337	125
Cloud	92	91	764

Courtesy of C. Woodcock group (Boston University)

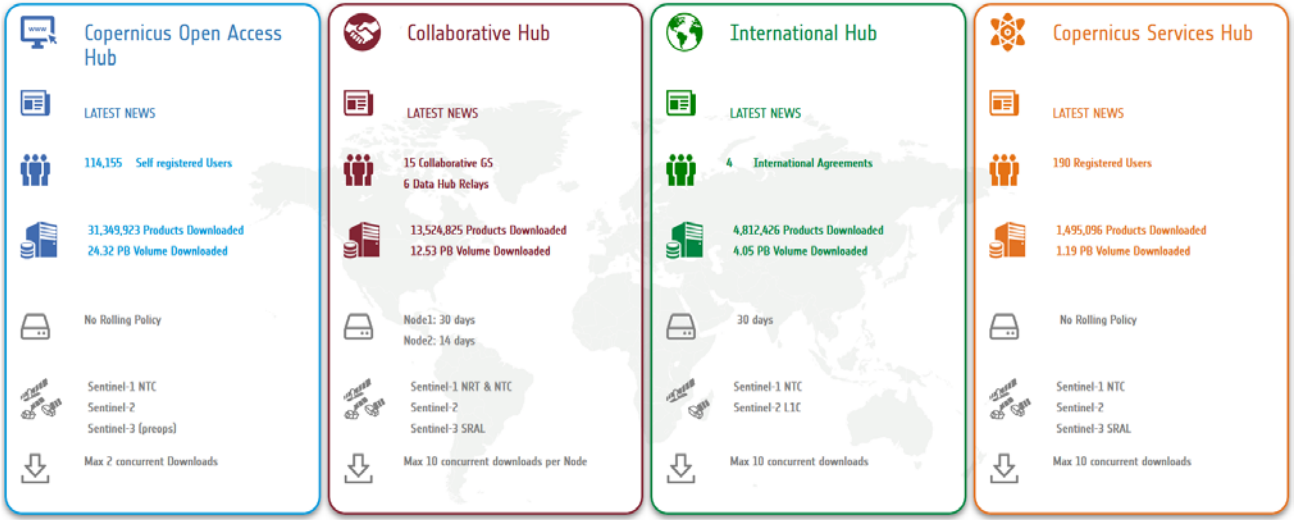
Updates from ESA
(Ferran Gascon, Benjamin Koetz)

Sentinel-2 Updates

- Sentinel-2A and -2B now acquiring global land area every 5 days
  - Antarctica every 10 days
- The pilot production of Level-2A surface reflectance products (over Europe and for Sentinel-2A only) is available on the Copernicus Open Access Hub and the Copernicus Services Data Hub
  - Systematic production using Sen2Cor algorithm is planned to start in Q1 2018 for Europe, and reach full global coverage in mid 2018.
- Updated Sentinel-2A spectral response functions for bands B01, B02 and B08 – these correct inaccurate spectral responses provided previously
  - Level 1 processor started using these 15 Jan 2018

Sentinels Data Access at ESA - Hubs

4 Sentinel data access hubs operated by ESA



Statistics at end December 2017

Also, access through:

- USGS Earth Explorer and other interfaces
- Google Earth Engine
- Amazon Web Services…

ESA R&D activities relevant for LCLUC in 2018/19

- **WorldCover:** Updating high resolution land cover maps for International Environmental Conventions, based on S1/S2 at continental scale
- **Dynamic Water Body Monitoring:** Addressing water and food security issues in Africa and SDG 6 monitoring with S1/S2
- **Land Degradation Neutrality:** monitor Land Degradation at high spatial resolution based on the changes in land cover, land productivity and carbon stocks as a support to UNCCD LDN and SDG 15.3.1
- **WorldPeatland:** Mapping and monitoring of peatland location and extent in Europe, the boreal zone and the tropics
- **Sen4Stat:** Demonstrate the potential of the Sentinel-1 & -2 missions in support of national agricultural statistical offices – e.g SDG 2.4 reporting.
- **Sen4RAPP:** Rangeland monitoring EO products in support of livestock carrying capacity in the context of GEOGLAM RAPP initiative

User Driven Thematic Conferences 2018/2019

2nd Mapping Water Bodies from Space Conference
27-28 March 2018 [ESA-ESRIN]

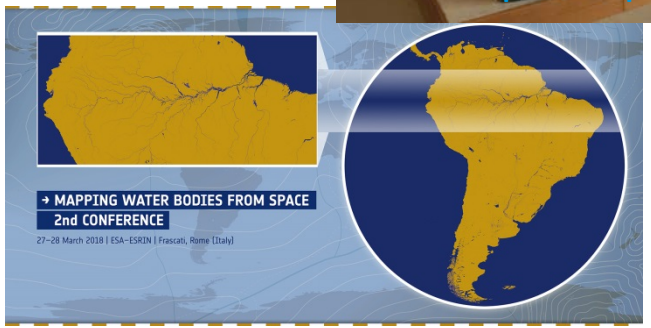
Background

In the frame of the EO Science for Society Programme
the 2nd Mapping Water Bodies from Space Conference.

The purpose of this conference is to provide scientists a
hand and up-to-date results from their on-going resea
data from past and current Satellites.

Participation

- ✓ ESA Principal Investigators
- ✓ Co-investigators
- ✓ Sentinel-1, Sentinel-2 and Sentinel-3 users
- ✓ Scientists
- ✓ Students
- ✓ Representatives from national, European and int
  adding industries



2nd Mapping Urban Areas from Space Conference
30-31 October 2018 [ESA-ESRIN]

WorldCover 2019 Conference
February 2019 [ESA-ESRIN]

Φ–Week: Innovation through Open Science & Transformative Technologies

In Conclusion…

MuSLI projects have demonstrated the ability to produce new land information products by fusing international sources of data
- long-term goal of CEOS (e.g. ”Multi-Resolution Interoperability” initiative)

Opens door to continental/global 30m products, similar to MODIS model

Questions for the future:
- long-term stewardship of MuSLI products as they “graduate” to Type 1
- measuring impact of MuSLI products within the land science community
- what is the vision (USGS, NASA) for operational higher level products at moderate resolution?