GFOI
Global Forest Observations Initiative

Baseline Global Acquisition Strategy For Satellite Data

2016 Implementation Report

for the
Global Forest Observations Initiative

Version 1.0
October 2017

CEOS GEO

Committee on Earth Observations (CEOS)

Ad-hoc Space Data Coordination Group (SDCG)

Global Baseline Data Acquisition Strategy for the Global Forest Observations Initiative (GFOI)

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11 October 2017

Committee on Earth Observation Satellites

1 Background and Scope

This document constitutes the CEOS SDCG 2016 Annual Implementation Report defined in the *SDCG Three-Year Work Plan 2015-2017* Baseline Global Data Acquisitions Outcome 1 describing the progress toward achieving the goals set forth in the *Global Baseline Acquisition Strategy for Global Forest Observations Initiative 2014 Update* (CEOS, 2014).

The primary purpose of the CEOS Global Baseline Data Acquisition Strategy for GFOI is to ensure systematic and sustained wall-to-wall acquisitions of forested areas world-wide, involving a number of so called *Core data streams*, i.e. CEOS satellite missions that can be used free-of-charge and openly for GFOI purposes (see main document, section 3.2), in order to ensure that national governments have routine access to sufficient satellite data for national forest monitoring purposes and for reporting of greenhouse gas emissions and forest carbon stocks to UNFCCC under the REDD+ provisions.

In 2016, ***the objectives set out in the Global Baseline Acquisition Strategy of global coverage of forested areas world-wide by freely available core data streams*** were met with USGS/NASA Landsat-7 and Landsat-8 and the European COPERNICUS Sentinel-2A and Sentinel-1A & B satellites. In addition, INPE provides free and open access to CBERS-4 data over Brazil, and JAXA JERS-1 SAR, ALOS PALSAR and ALOS-2 PALSAR-2 annual 25 m mosaics provide free and open access to SAR data.

2 Space Data Availability

2.1 Core Data Streams in 2016

Landsat 7 & 8 each provide a 16-day revisit. Together they provide an 8-day global revisit. The Landsat 9 launch date holds for a 2021 launch to continue the 8-day revisit after Landsat 7 is decommissioned. Following the successful launch of Sentinel-2B, as of 7 July 2017, Sentinel-2 A & B each provide a 10-day revisit over Europe, Africa and Greenland (5-day together) and a 20-day (10-day together) revisit over the rest of the world. The combined revisit for Landsat 7 & 8 and Sentinel-2A & B will be 2-4 days - once Sentinel-2 finishes their ramp-up - densifying the annual combined time series and increasing the probability of cloud free data. In combination with Sentinel-1A & B robust coverage of world-wide forested areas are available. Global coverage by Sentinel-1 A & B SAR C Band data complements the optical data provided by Sentinel-2 and Landsat further ensuring that global coverage is available even for persistently cloudy areas. Additionally, JAXA provides an annual global mosaic of ALOS-2 PALSAR-2 L-band SAR data.

The current CEOS missions extend the environmental record of earlier open access Landsat 1-5 (1972), SPOT 1-5 (1985), CBERS 1-2 (1999), and TERRA ASTER (1999). These data, in addition to regional and commercial data, provide the baseline and land cover variability data needed for successful forest monitoring.

2016 Landsat Data availability

Acquisitions by the Landsat-7 and Landsat-8 missions are guided by Long Term Acquisition Plans (LTAP). The plans are used to set priorities for the acquisition of Landsat images as a function of seasonality; land definition; time since last successful acquisition, forecasted cloud cover; cloud climatology; and sun angle. Each day the opportunities are ranked by their priorities and images are acquired up to the daily limit. Physical constraints, such as duty cycle, manoeuvres, on-board memory and downlink opportunities, may limit acquisition opportunities. Landsat is currently the only core mission acquiring thermal data.

Landsat-7 & -8 are managed as a constellation. As of November 2013, Landsat-7 is managed as a continental mission (Figure 2.1). Open ocean, islands and Antarctica are no longer routinely imaged with Landsat-7. The focus of Landsat-7 on continental land masses increased the average number of daily images from 375 to 439 (91.6% of 479 opportunities), while at the same time reducing the number of times the sensor needs to be power cycled. The 22% missing data in the Landsat-7 images results in a no-data rate similar to 22% cloud cover. However, cloud-free Landsat-7 data is preferred to 22% cloud cover, since cloud contamination and cloud shadow will have effects beyond the areas identified as clouds.

For mid-latitude (57 degrees North and South) scenes (rows 21 through 104) all Landsat 8 scenes, not pre-empted by maneuvers or calibration, should be collected (Figure 2.2). High latitude scenes North and South of these rows have more than 50% overlap between paths providing an 8-day or less revisit time, so the priority is decreased as a function of overlap. However even at high latitudes more than 90% of the day-lit opportunities are acquired yielding an effective 4-day or less revisit at high latitudes.

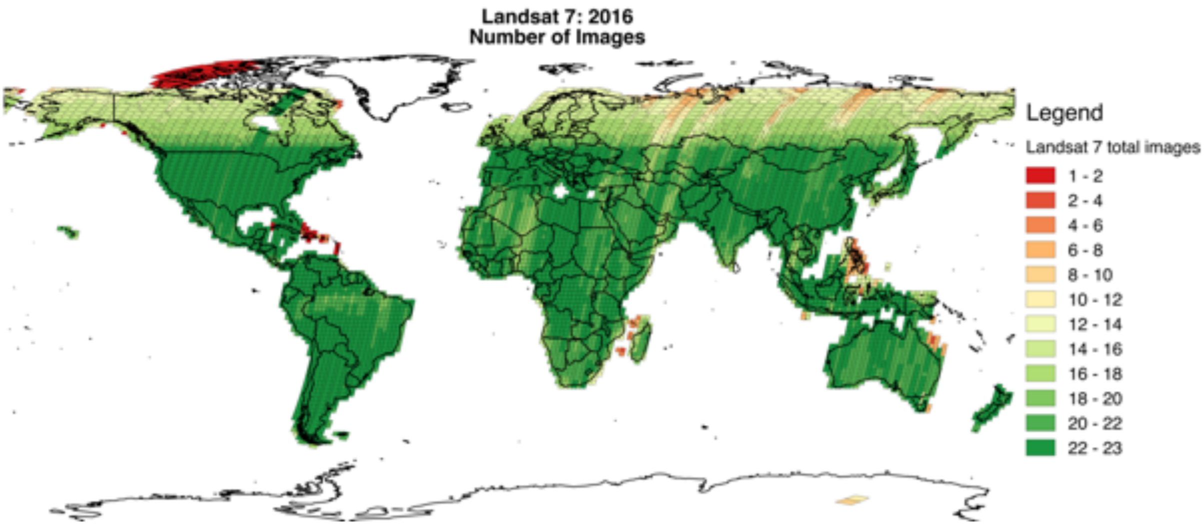

Figure 2.1. Landsat 7 acquired 99.6% of the day-lit land opportunities over tropical and temperate zone countries in 2016.

Together, the Landsat-7 and Landsat-8 missions offer an 8-day minimum revisit time, with each individual satellite revisiting every 16 days. Data are acquired during every opportunity over U.S. territory, and within the Brazilian and Australian ground station masks. Over the continental land masses in 2016 over 40 images (23 with Landsat 8 and 21 with Landsat 7) were acquired for scenes that are not sun limited. For oceanic island nations 23 images are acquired each year with Landsat 8.

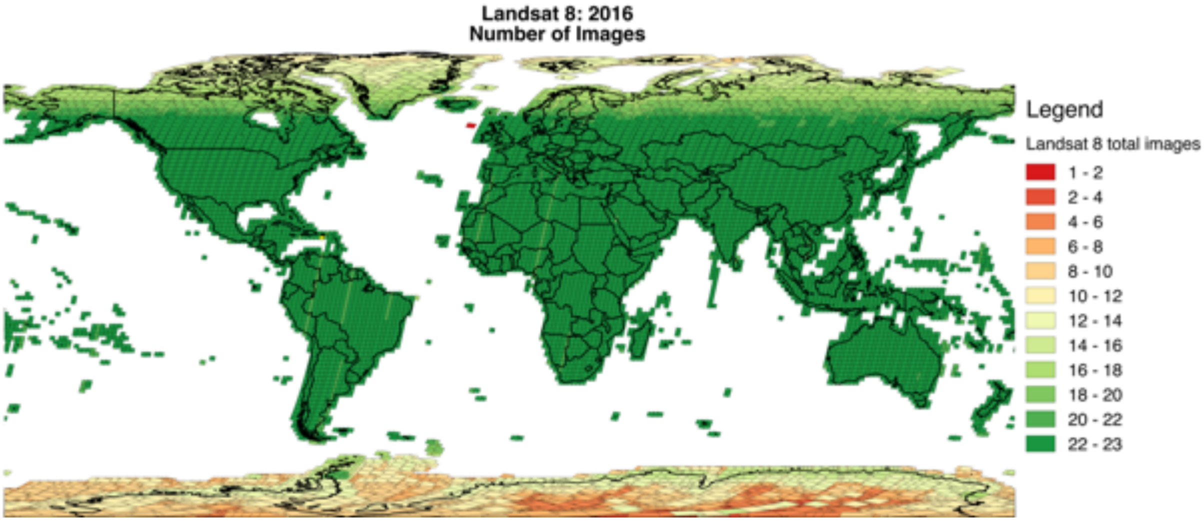

Figure 2.2. Landsat 8 acquired over 96.5% of all candidate images in 2016 including Arctic and Antarctic scenes

An 8-day revisit time is not sufficient to create annual cloud-free mosaics in regions with persistent cloud cover (Figure 2.3 & Table 2.1). The change to the Landsat-7 continental model increased the probability of acquiring cloud-free images and helped compensate for the missing data caused by the scan line corrector failure on Landsat-7. Multiple acquisitions will often be necessary to provide annual complete data coverage to compensate for persistent clouds and Landsat-7 missing data. For thirty scenes, the best cloud cover was over 20 per cent (Table 2.1). The highest minimum cloud cover is 43.5%.

Percent cloud cover	<=5	>5 & <=10	>10 & <=20	>20 & <=30	>30 & <=40	>40
Number of Scenes	15,581	227	142	26	3	1

Table 2.1. Distribution of best cloud cover for 2016.

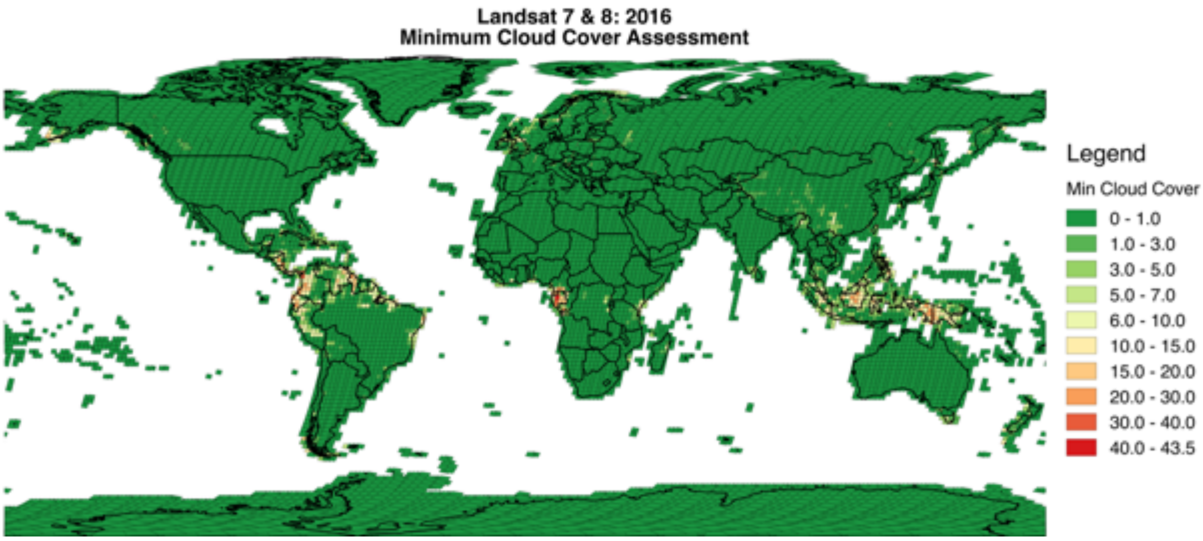

Figure 2.3. Minimum cloud cover for each scene for Landsat 7 & 8 during 2016.

With 8-day revisit, Landsat images the world up to 46 times a year not taking into account side lap between paths. The two maps below show the distribution of the number of Landsat scenes with less than less than 20% cloud cover (Figure 2.4) and with less than 60% cloud cover (Figure 2.5). These are two thresholds that can be used to estimate the value of scenes for cloud compositing and for use in data cubes. Scenes with less than 20% cloud cover are likely to contain pixels with minimal cloud contamination. Scenes that are less than 60% cloud cover may have pixels with minimal cloud contamination. It cannot be assumed that multiple scenes will result in cloud free composites, since cloudy regions often persist through time. These are very rough rules of thumb to emphasize the importance of frequent observations to improve the likelihood of acquiring a significant number of observations of the Earth. Large portions of the Earth have fewer than ten 20% or better cloud cover scenes per year.

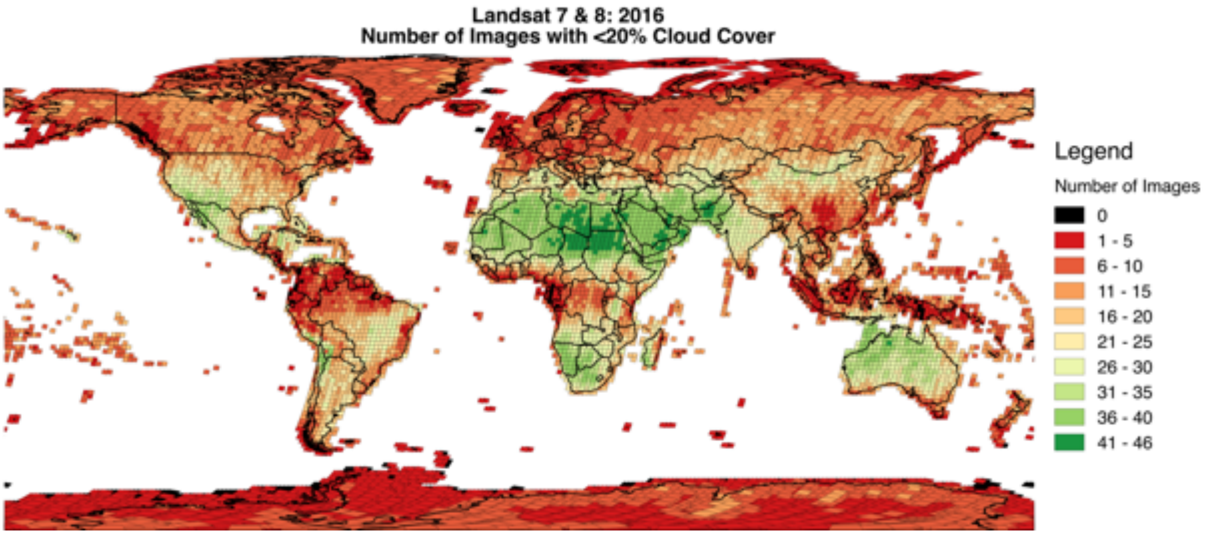

Figure 2.4. Number of images with less than 20% cloud cover during 2016.

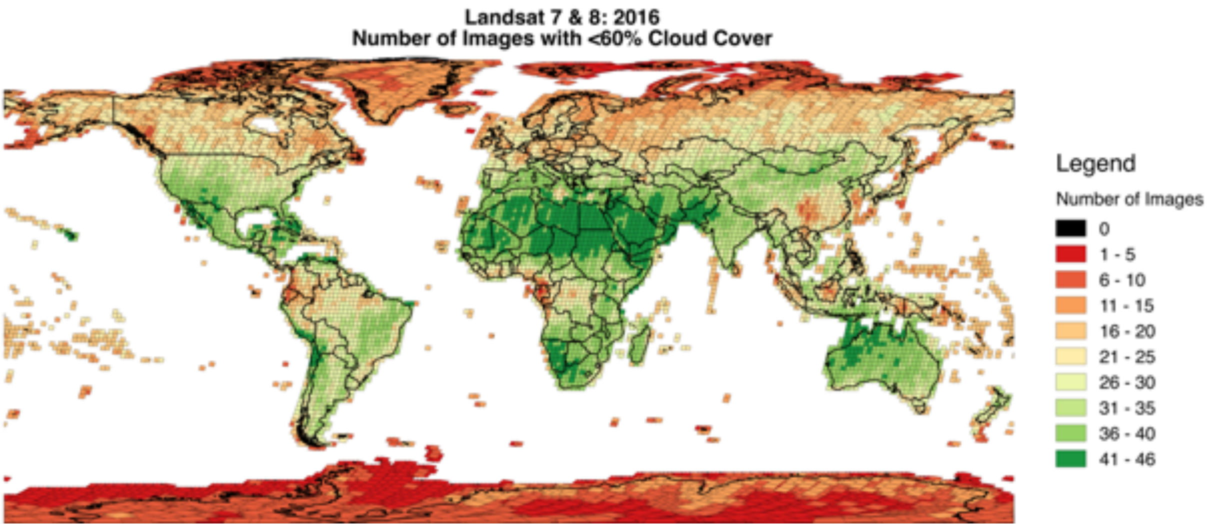

Figure 2.5. Number of images with less than 60% cloud cover during 2016.

The combination of Landsat-7 and -8 provided global coverage in 2016. The question for GFOI is whether the number of acquisitions over the priority countries has been sufficient to obtain at least one clear-sky coverage per year, which is the minimum optical data requirement for GFOI. It is unlikely that this criterion can be met even with the 2-4 day revisit possible with Landsat and Sentinel-2 in all countries. SAR data will be required to fully meet the requirement for global forest cover monitoring.

In 2016 Landsat changed to a collection based data management approach to improve consistency of the product for time series analysis. The number of Landsat surface reflectance products disseminated currently exceeds the number of top of atmosphere data products disseminated to the user community by USGS. All Landsat data are available for download from USGS (landsat.usgs.gov) using EarthExplorer (earthexplorer.usgs.gov) or GloVis (glovis.usgs.gov). Landsat data are also available from other sources including universities, commercial organizations and other CEOS agencies.

Sentinel-1

The Sentinel-1 mission comprises a constellation of two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar imaging, enabling them to acquire imagery regardless of the weather. Sentinel-1A was launched on 3 April 2014 and Sentinel-1B followed on 25 April 2016. The satellites work in a pre-programmed operation mode to avoid conflicts and to produce a consistent long-term data archive built for applications based on long time series.

Sentinel-1A began its operation ramp-up phase in September 2014 until it reached full operational status in June 2015. Sentinel-1B completed its commissioning phase in September 2016, ramping-up for mission operations qualification until it the overall system reached its nominal routine operations in May 2017. During that period it increased gradually the use of the Interferometric Wide Swath mode (IW) in dual polarisation, which is the preferred mode for forestry applications.

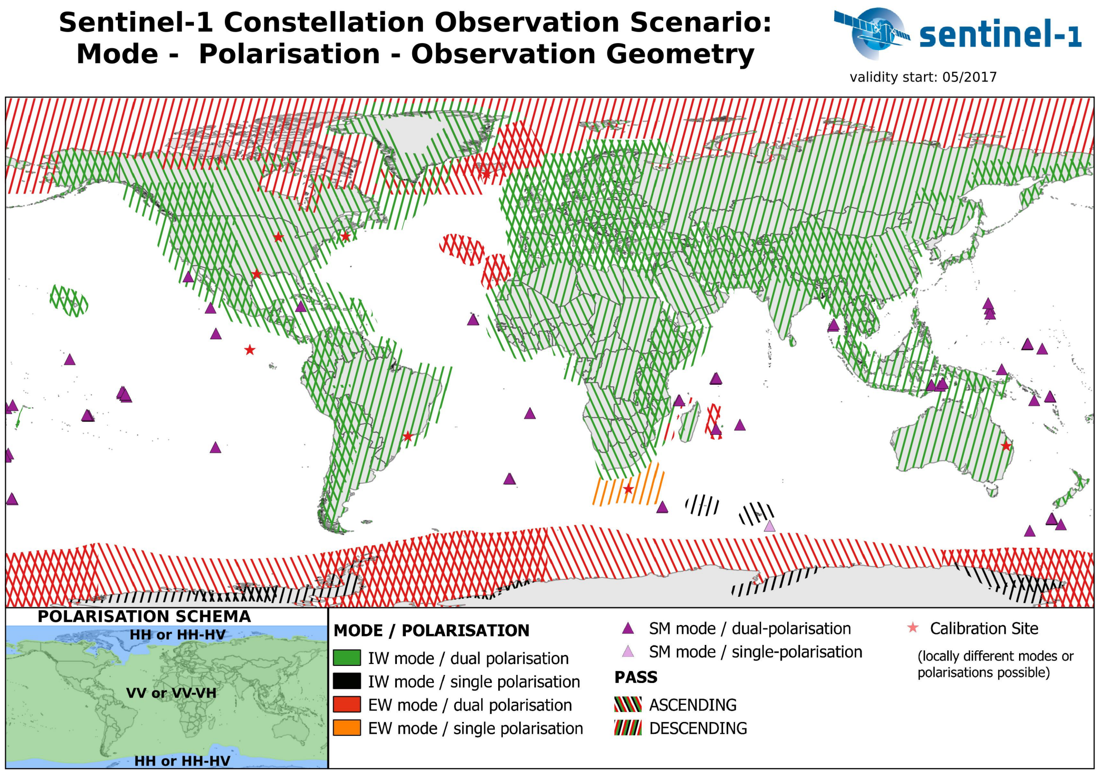

Figure 2.6 SAR mode, polarisation and observation geometry of the Sentinel-1 system

During the ramp-up exploitation phase, the Sentinel-1 observation plan gradually evolved in line with the increasing operational capacity. The maps in Figure 2.6 and 2.7 describe the overall Sentinel-1 constellation observation scenario, in terms of SAR mode, polarisation, observation geometry, revisit and coverage frequency, starting as of May 2017.

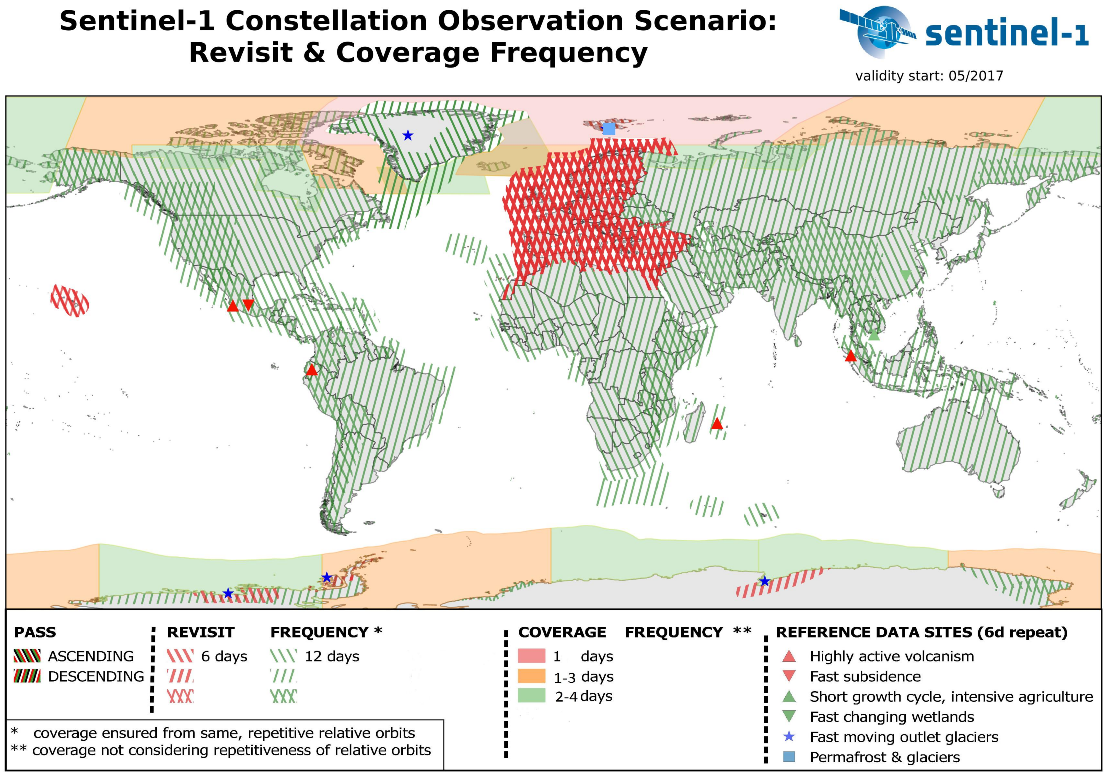

Figure 2.7 nominal revisit and coverage frequency of the Sentinel-1 system starting as of May 2017.

KML files providing detailed information on the planned acquisitions, regularly published on Sentinel Online.

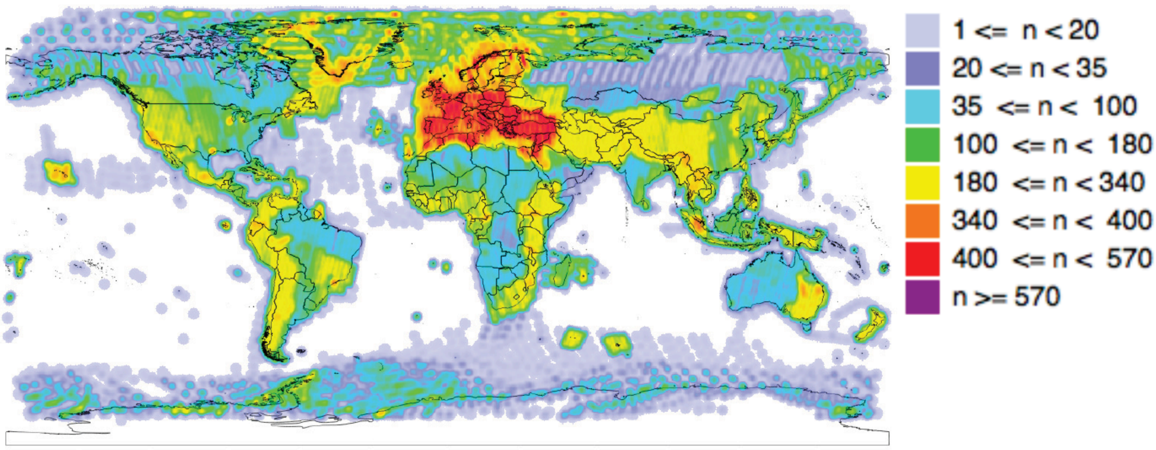

Figure 2.8 Heat map of Sentinel-1 products published during year 2016

The heat map in figure 2.8 shows the global coverage of the Sentinel-1 data published in year

2016, with the highest number of products available over Europe and maritime monitoring areas. Other hot spot (red) areas correspond to calibration sites and places of interest for particular campaigns, such as active tectonic areas. The high-level operation plan included campaigns to support forest monitoring international activities in IW dual pol, as part of GFOI activities in particular, in support of REDD+. GFOI sites included areas in Vietnam, Ecuador, Colombia, Peru, Amazon, Tanzania and Lake Victoria region. On the other end North-western Brazil and the Democratic Republic of Congo were areas in the tropics with fewer coverage.

The high level observation plan for Sentinel-1 foresees now that all global landmasses are regularly covered at least every 12 days in a stable one pass IWS mode, and mainly in VV-VH polarization, which is a great step forward for operational forest monitoring world-wide. The Sentinel-1 mission provides global and routine coverage, with a systematic production scenario, an open and free data access, and the long-term perspective.

Sentinel-2

The Sentinel-2 mission comprises a constellation of two polar-orbiting satellites, operating a multispectral imager with 13 bands. Sentinel-2A was launched on 23 June 2015 and Sentinel-2B on 7 March 2017. The commissioning phase of Sentinel-2A ended successfully in October 2015, followed by a ramp-up phase: Europe, Africa and Greenland are covered systematically every 10 days (each cycle), whereas the rest of the world is covered every 20 days. The Sentinel-2 baseline observation scenario will systematically cover all land surfaces between 56° South latitude and 84° North latitude. Data from Sentinel-2 A is provided routinely since 3 December 2015.

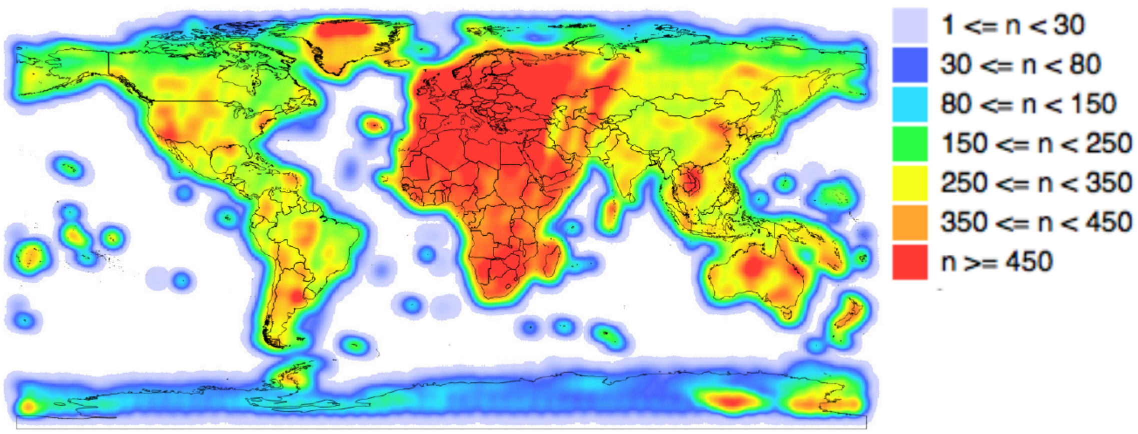

Figure 2.9 Heat map of Sentinel-2 products published during year 2016

While the Sentinel-1 heat map shows a variable density acquisition rate over different geographical areas, the heat map in Figure 2.9 shows that Sentinel-2A was focused during the ramp-up phase on European and African land masses, but aimed at achieving more evenly spread global coverage.

Sentinel Data Access

The Sentinel Data Access System provides to different user typologies free and open access to Copernicus Sentinel data products. In 2016 it grew to four types of data hubs serving different user communities (Figure 2.10)

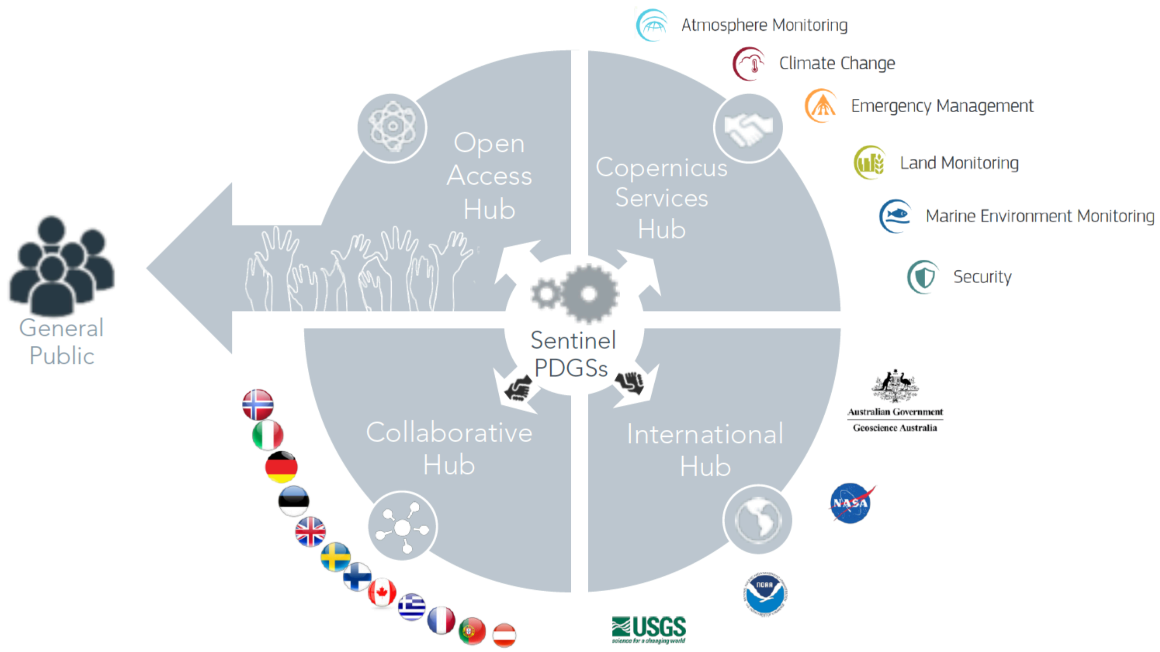

Figure 2.10 the Sentinel Data Access System configuration by end 2016

For GFOI the most important access point is the Copernicus Open Access Hub (previously known as the Sentinel Scientific Data Hub) at http://scihub.copernicus.eu which offers to all users free, full and open access to Copernicus Sentinel data. It provides an open source hub interface and offers the possibility to automatically download data via scripts. A maximum of 2 concurrent downloads per user is allowed in order to ensure a download capacity for all users. The automatic and immediate self-registration is available to anyone. End of 2016 about 60,000 users have self-registered on the Copernicus Open Access Hub.

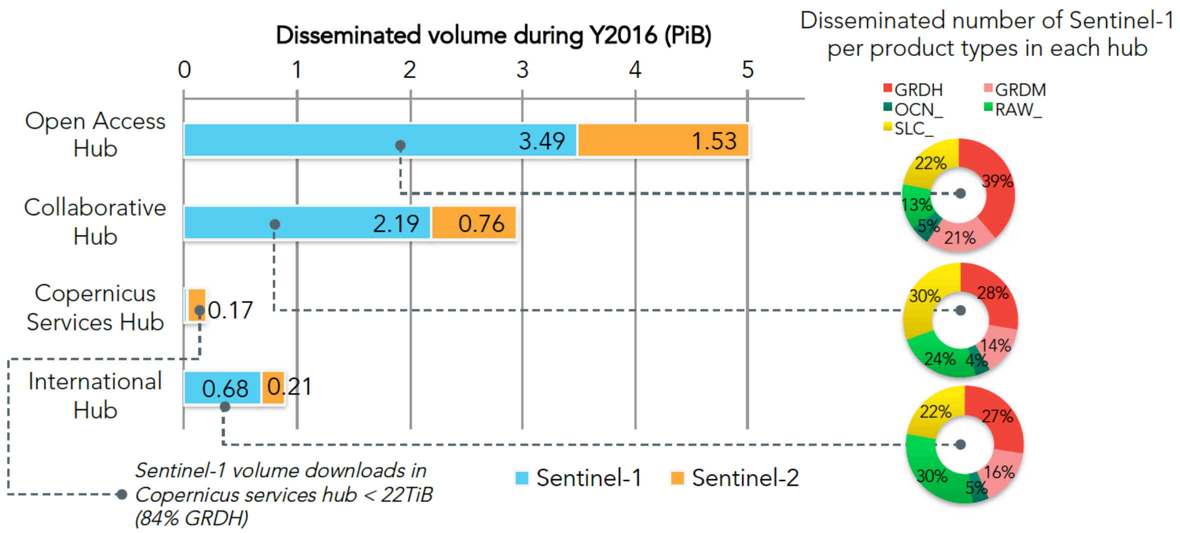

Figure 2.11 Sentinel-1 and Sentinel-2A disseminating volume in 2016 per hub and product type

The Copernicus Service Hub is the preferential access area for the six Copernicus services. The Collaborative Hub was expanded in 2016 to provide access to all GMES/Copernicus participating states. As of spring 2016, international partners mirror sites have started disseminating towards own national communities. USGS, NASA, NOAA and the Australian government are the four current mirror sites served by the International Hub.

More than 6 million product downloads have been made by users, corresponding to approximately 9 PB of data. About 1 million Sentinel-1 products were available on-line for download, representing more than 1.4 PB of SAR data. For Sentinel-2 about 400,000 Level-1C products were available for download, cumulating a total volume of more than 500 TB.

2.2 Other Core and Contributing Data Streams

The phasing of the strategy applies to coordination of the necessary satellite data acquisitions consistent with national reporting requirements. The strategy has been:

- working to ensure continuity of coverage of those countries that are seeking active participation in GFOI and have engaged in related capacity building activities;
- expanding the coverage stepwise to a full global one in 2016;
- include other core data streams dependent on their launch and generally consistent with their acquisition capacities; i.e. CONAE/ASI SAOCOM-1A and -1B (now 2017+)

ALOS-2 with its L-band sensor PALSAR-2 was launched on 24 May 2014 and has been fully operational in 2016. One of its objectives is global monitoring of tropical forest to identify carbon sinks. As for ALOS-1 JAXA makes annual global mosaics of ALOS-2 data free of charge available in 25 m resolution (Figure 2.12). In 2016, JAXA also released historical 25 m JERS-1 SAR mosaic data; global for the year 1996 and pan-tropical coverage for 1993-1998.

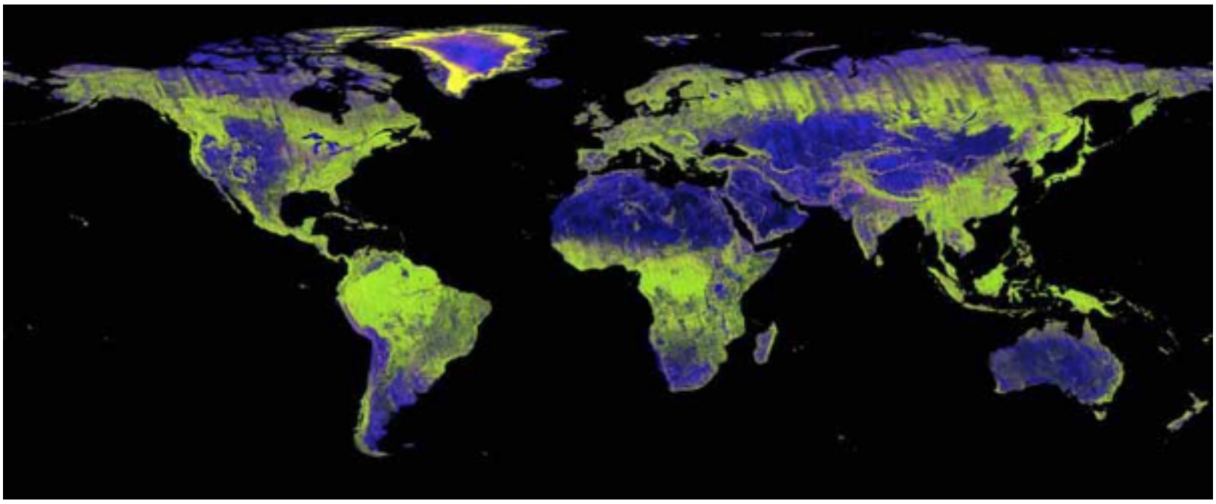

Figure 2.12 ALOS-2 PALSAR-2 Global Mosaic

CBERS-4 a joint mission from INPE/CRESDA was launched 7 December 2014. With its four sensors on board it contributes to increase regional coverage in South America, China and Central Africa.

Other CEOS agencies' related missions, such as optical high-resolution missions, (e.g. RapidEye and the SPOT series), and radar missions (e.g. ALOS-2, Radarsat-2, TerraSAR-X and TanDEM-X) can supplement the core missions for persistently cloudy areas in addition to supporting validation and technical studies.

3 Conclusions

As a global mission with a long-term acquisition plan, the GFOI global mandate has been met with Landsat 7 & 8, Sentinel-2A, Sentinel-1A and the ALOS -2 annual mosaic. These core missions acquired operationally data for all of 2016. Sentinel-1B, and CBERS-4 became available during 2016.

All GFOI countries were revisited nearly every 8 days by Landsat with the exception of oceanic countries, which were revisited every 16 days. Ninety-nine per cent of the Landsat images in a best available image mosaics have less than 10% cloud cover. Sentinel-2A has still been ramping-up towards its full operational capacity to revisit the land surfaces every 10 days. It achieved that for Europe, Africa and Greenland, but the rest of the world is imaged every 20 days. In combination of these optical sensors it is very likely that an annual cloud free mosaic for all forested countries will be possible. Seasonal mosaics would still be difficult to produce in most countries, where SAR data will be needed to complement and supplement optical images.

Sentinel-1 constellation is now operating within a new global acquisition strategy to map land areas at least every 12 days. For regions, such as the persistently northwest portion of South America, the Western Congo basin and South East Asia it provides up to date information on recent forest disturbances. Also ALOS-2 follows the long tradition of a global acquisition strategy as its precursors JERS and ALOS-1 and provides with its annual mosaics complementary information. Additional to forest disturbances its L-band SAR is more sensitive to the vegetation cover and can provide biomass estimates for levels of about 100 tons per hectare.

With these core missions we achieved with high certainty the basic requirement of at least one cloud free optical observation and two SAR data sets covering all forest areas globally. Key to this success were the systematic acquisition strategies of the satellites, the long-term observation scenarios and the fruitful cooperation between space agencies.

4 References

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