GFOI

Global Forest Observations Initiative

Global Baseline Data Acquisition Strategy: 2013 Implementation Report

Annex to the 2014 Update

for the Global Forest Observations Initiative

Version 1.0
for CEOS SIT-29, April 2014

CEOS
Committee on Earth Observation Satellites

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)

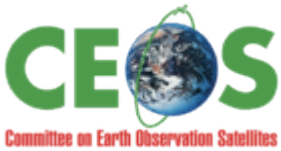
–

Annex B

2013 Implementation Report

Version 1.0

8 April 2014



1 Background and Scope

This document constitutes Annex B to the CEOS SDCG *Global Baseline Data Acquisition Strategy for GFOI, 2014 Update* (CEOS SDCG, 2014a), defined as Element 1 of the *CEOS Data Strategy for GFOI and FCT* (CEOS, 2011). It specifically reports on the 2013 implementation of the Element 1 Strategy in accordance with the implementation plan for 2013 (CEOS SDCG, 2013) which was endorsed by the CEOS Strategic Implementation Team (SIT) at the SIT-28 meeting in March, 2013.

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..

The scope of the Global Baseline Data Acquisition Strategy is limited to acquisition planning and coordination of acquisition component only, while issues relating to the physical provision of the satellite data acquired are dealt with under Element 2 of the CEOS Data Strategy, the *SDCG Space Data Services Strategy* (CEOS SDCG, 2014b).

As outlined in section 3.3 of the main document, the Global Baseline Data Acquisition Strategy is being implemented in a phased approach to reflect the schedule of gradually increasing availability of the anticipated *Core data streams* between now and 2016. In 2013, 15 countries were defined by GFOI as first priority in case of resource limitations by the *Core data streams*, which in 2013 were limited to USGS/NASALandsat-7 and Landsat-8.

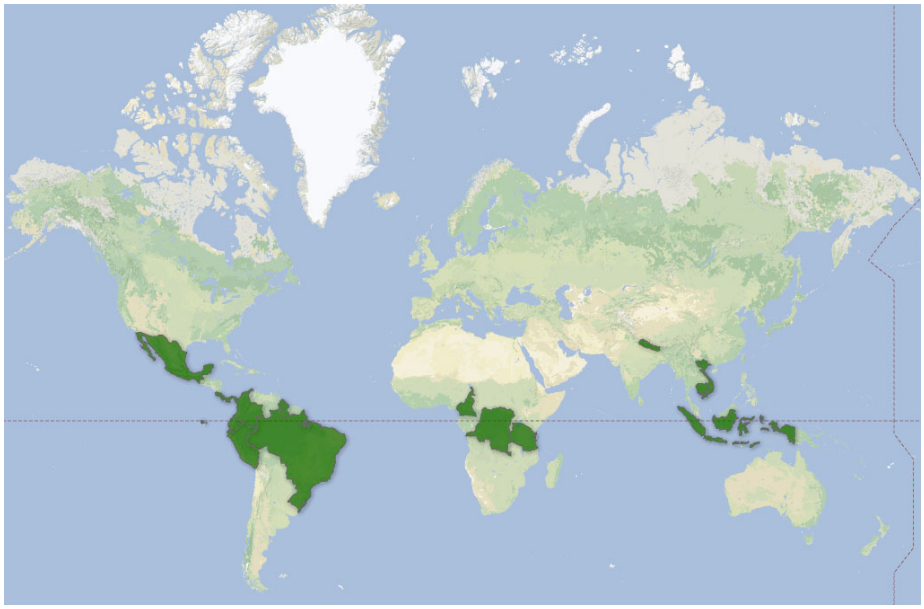


Figure 1-1 – GFOI priority countries in the 2013 Implementation Plan

2 Space Data Availability

2.1 Core Data Streams in 2013

The Landsat-7 and -8 were the only of the *Core data streams* that were in operations in 2013, with Landsat-8 data available after 15 April. The two satellites were found to provide adequate frequency of coverage for GFOI requirements in 2013 for all regions of the world other than those most affected by persistent cloud cover. The coverage available will be discussed in general below and in detail in section 3.

Landsat and the Landsat Long Term Acquisition Plan

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, maneuvers, on-board memory and downlink opportunities, may limit acquisition opportunities.

Landsat-7 and -8 are managed as a constellation. As of November 2013, Landsat-7 is managed as a continental mission. Open ocean, islands and Antarctica are no longer routinely imaged with Landsat-7. The focus of Landsat-7 on continental land masses will increase the average number of daily images from 375 to 434 (90.5% of 479 opportunities), while at the same time reducing the number of times the sensor needs to be power cycled. Between June and August 2013, the average increased from 392 to 470 images per day (85.5% of 550 opportunities). Between December 2013 and February 2014, the average increased from 354 to 357 images per day (99% of 358 opportunities). 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. Landsat 8 has acquired 550 images per day since commissioning.

Together, the Landsat-7 and Landsat-8 missions offer an 8-day 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. Globally, the LTAP aims at achieving at least four seasonal global land coverages each year optimized for cloud cover.

An 8-day revisit time is not sufficient to create annual cloud-free mosaics in regions with persistent cloud cover. The change to the Landsat-7 continental model increased the probability of acquiring cloud-free images in November and December of 2013 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.

The seasonality file has four variables: start date, end data, recurrence and priority. The seasonality file only contains records for Worldwide Reference System (WRS) path/row pairs that contain land. Each WRS path/row pair that contains land has at least one record.

The start and end dates define seasons. A recurrence value of either once or always is associated with each record. The once rule seeks to acquire one successful image during the "season." A successful image is one with a cloud cover assessment of less than 20 percent. When the criterion is met the record is "turned off." The priority is increased after every failed attempt to acquire a "successful" image. If the recurrence is set to "always", the priority is reset to the base priority after a successful acquisition. There will rarely be a gap of more than three images in the archive, when recurrence is set to "always." As of the implementation of the Landsat-7 continental model acquire "once" option is not used for Landsat 7. Landsat 8 only uses the acquire "once" in selected Antarctica regions.

Cloud avoidance is implemented as a function of cloud predictions, cloud climatology and cloud fraction of acquired images. Cloud climatology (Figure 2.1) is the long term monthly average cloud cover estimate. The cloud climatology is compared to a cloud prediction. If the cloud prediction is lower than the cloud climatology, then the priority is boosted. This has the effect of increasing the priority over persistently cloudy regions particularly when augmented by the missed opportunity boost that is provided if a "successful" acquisition is not acquired. For example, if the cloud climatology is 80%, then a cloud prediction of 60% will receive a significant boost, whereas if the cloud climatology is 10%, then a cloud prediction of 20% would not receive a priority boost. This logic has the result of reallocating acquisitions from arid to persistently cloudy areas.

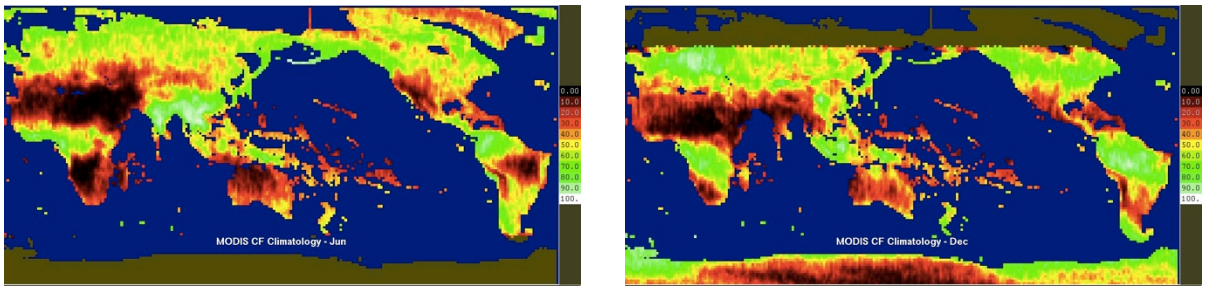


Figure 2.1. Cloud climatology for June and December: green to white regions have high probability of clouds and black to red regions have a low probability of clouds. The grey areas are excluded due to low sun elevations.

2013 Landsat Data availability

The combination of Landsat-7 and -8 provided global coverage in 2013. 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.

With the Landsat Long-Term Acquisition Plan (LTAP) plans, the continental USA, and the regions within station masks of the Brazilian and Australian ground stations in Cuiaba, Alice Springs and Darwin (major part of South America, Australia, Papua New Guinea and the southern islands of Indonesia) are foreseen to be covered by every acquisition opportunity.

The goal is to have cloud free global coverage comprised of images with zero cloud cover. However this is an unattainable goal for one or even two satellites. Even daily acquisitions is not sufficient to acquire annual or seasonal coverage, as has been shown with models using MODIS daily observations. Alternatives include:

1) Multiple images: using a time series of images will increase the probability of cloud free pixels. Multiple images increase the data volume. Cloud compositing prior to delivery of data creates a complex image where all pixels are not from the same date. The use of multiple images increases the analysis complexity.
2) Additional moderate resolution core sensors: The Sentinel-2 satellites will significantly reduce the repeat cycle for global coverage from 8 days to 4-5 days doubling the number of available temporal samples. The availability of CBERS for South American and Africa tropical zones will further decrease the repeat cycle for these most critical climate zones.
3) Fusion with low-resolution core sensors: increase the probability of cloud free images, but with lower resolution fill.
4) Fusion with SAR sensors: Best solution for persistently cloudy areas. The use of SAR and optical data for analysis increase the complexity of the analysis and requires cross validation of derived information products. Costs may be associated with access to the data.
5) Tasking high and moderate resolution space and aerial sensors: Commercial data can be acquired to fill gaps in coverage.

Data, that can contribute to complete cloud free coverage, are briefly discussed in section 2.2. See Baseline Global Acquisition Strategy for 2013 and the Methodology and Guidance Document for detailed analysis.

The 15 GFOI countries for 2013 are covered by 2216 Landsat scenes. The statistics and maps below represent the scenes acquired between 1 January 2013 and 31 December 2013. Landsat 7 had 23 opportunities and Landsat 8 had 18 opportunities to acquire images for each path/row in 2013. Landsat 8 acquired its first image on 18 March, reached final orbit on 15 April and was formally declared operational on 30 May. Images acquired since 15 April are included in the statistics and maps.

The Landsat 7 distribution of the number of images for each path/row is shown in Figure 2.2. The three graphs show the distribution of the total number of images, the number of images with less than 20% cloud cover, and the number of images with less than 60% cloud cover. Table 2.2 shows the cumulative proportions. 53.3% of the path/rows have 18 or fewer images. Of those 52% of the path/rows have 4 or fewer images with less than 20% cloud cover and 50.2% have at least 10 images with less than 60% cloud cover. 7.1% of the path/rows have no images with less than 20% cloud cover. 1.9% of the path/rows have two or fewer images with less than 60% cloud cover. For these path/rows an annual cloud free sample with Landsat 7 only is unlikely.

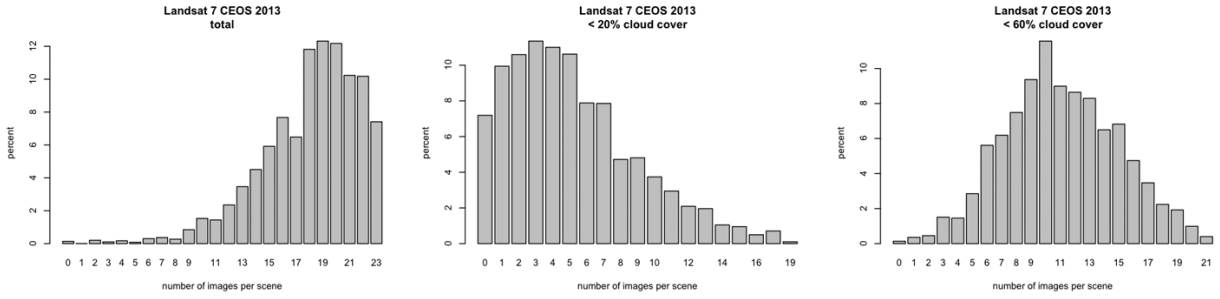


Figure 2.2. The distribution of the number of Landsat 7 images acquired per path/row for GFOI 2013 countries.

Table 2.2. Cumulative distribution of Landsat 7 scenes for GFOI countries in 2013.

#images	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
total	0.4	0.5	1.1	1.4	1.8	2	2.6	3.2	3.7	4.9	7	8.9	11.8	16	21	27.4	35.3	41.8	53.3	64.7	75.8	84.9	93.6	100
<20%	7.1	17.3	28.7	40.7	52	62.6	70.4	78	82.5	87	90.6	93.4	95.3	97.1	98	98.9	99.3	99.9		100				
<60%	0.4	0.9	1.9	3.7	5.4	8.5	14.6	21.3	29.1	38.7	50.2	59	67.3	75.2	81.3	87.7	92	95.2	97.1	98.8	99.7	100		

The Landsat 8 distribution of the number of images for each path/row is shown in Figure 2.3. Table 2.3 shows the cumulative proportions. 53.2% of the path/rows have 14 or fewer images. 50.4% of the path/rows have 4 or fewer images with less than 20% cloud cover and 54.6% have 10 or fewer images with less than 60% cloud cover. 7.6% of the path/rows have no images with less than 20% cloud cover. 1.4% of the path/rows have two or fewer images with less than 60% cloud cover. For these path/rows an annual cloud free sample with Landsat 8 only is unlikely.

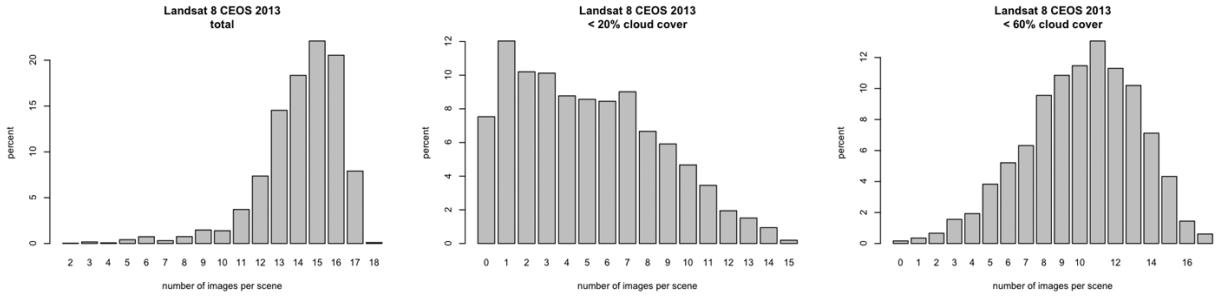


Figure 2.3. The distribution of the number of Landsat 8 images acquired per path/row for GFOI 2013 countries.

Table 2.3. Cumulative distribution of Landsat 8 scenes for GFOI countries in 2013.

"	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
total			0.3	0.6	0.8	1.4	2.6	3.1	4.3	6.4	8	12.2	20.2	35.1	53.2	74.2	92.9	99.9	100					
<20%	7.6	20	30.9	41.5	50.4	59.3	67.6	76.4	82.8	88.3	92.7	95.8	97.6	99	99.8	100								
<60%	0.2	0.5	1.4	3.5	5.7	10	15.7	22.4	32.1	43.2	54.6	67.3	78	87.6	94.2	98.1	99.4	100						

As would be expected the statistics for Landsat 7 and 8 are very consistent. The maps (Figure 2.4-6) below represent the data acquired during 2013: up to 23 opportunities since 1 January for Landsat 7 and up to 18 opportunities since 15 April for Landsat 8. Even for scenes where nearly all images are acquired, many scenes exist with no images with better than 20% cloud cover. Images that are not acquired are nearly always rejected due to excessive cloud cover. Cloud cover analysis with daily MODIS data has shown that rarely are high quality images rejected.

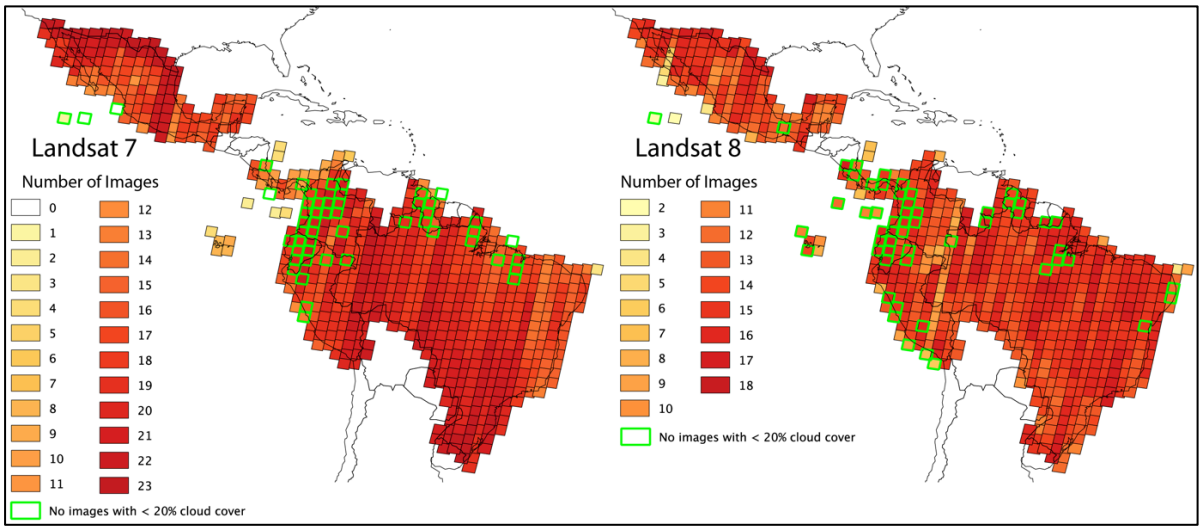


Figure 2.4. The spatial distribution of Landsat 7 and 8 images acquired for GFOI countries in the Americas. Scenes with green boundaries have no images with less than 20% cloud cover

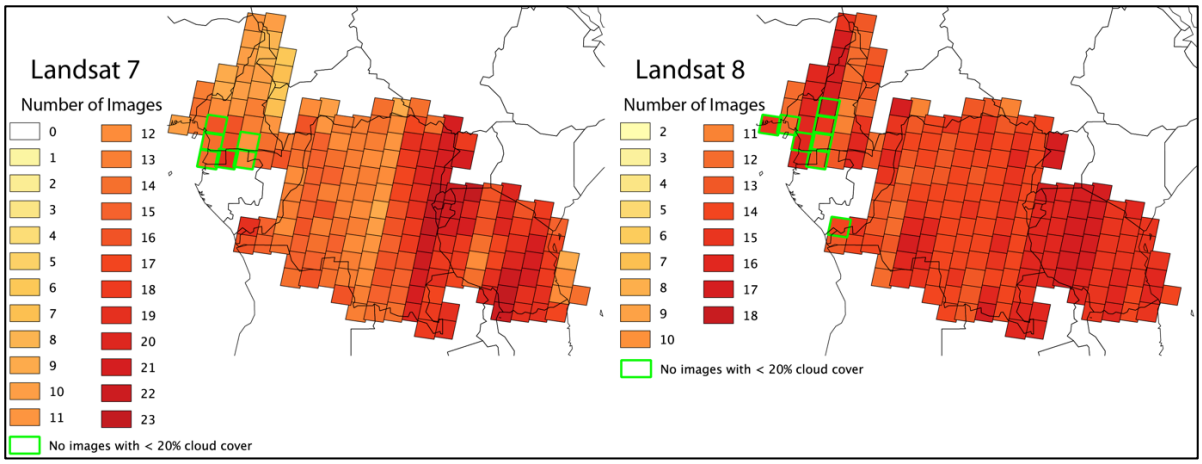


Figure 2.5. The spatial distribution of Landsat 7 and 8 images acquired for GFOI countries in Africa. The scenes with green boundaries have no images with less than 20% cloud cover

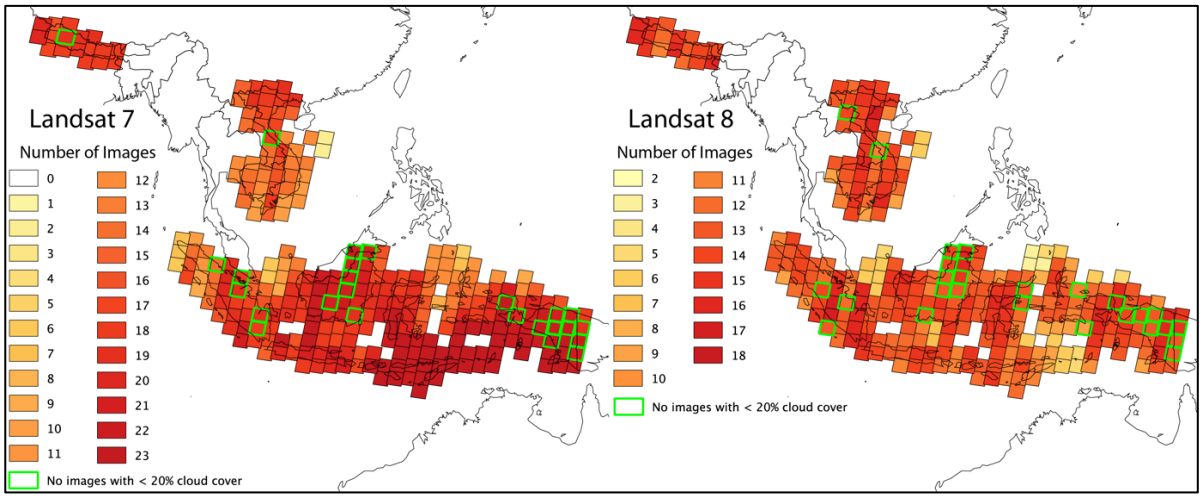


Figure 2.6. The spatial distribution of Landsat 7 and 8 images acquired for GFOI countries in Asia. The scenes with green boundaries have no images with less than 20% cloud cover.

The distribution of the images through time and the distribution of the clouds are not shown. However it can be assumed that the images are not evenly distributed throughout the year and the distribution of the clouds is not random. Country statistics and maps are provided in section 3 to help illuminate seasonal data availability.

To get an idea of the best possible coverage using both Landsat 7 and 8, the best cloud cover image for each path row was identified (Figure 2.7). Over 30 images are available for most path row or on average one image every two weeks. The path/rows where only a few images were acquired are usually small islands or open water. Table 2.4 shows the distribution of best images for Landsat 7, Landsat 8 and both Landsat 7 and 8. Forty per cent of the best images have close to zero clouds. Seventy per cent of the best images have cloud cover assessments better than 3%. Ninety per cent of the best images have cloud cover assessments better than 10%. The "worst" best image (path 102; row 63) in Indonesia was 42.42% cloud covered. The next "worst" best image (path 10; row 5) in Panama/Colombia was 41.08% cloud covered. Predictably either Landsat individually performs significantly worse than the two together. The worse success rate of Landsat 8 can be contributed to the no data available through 15 April. Figure 2.8 shows the spatial distribution of the least cloudy images.

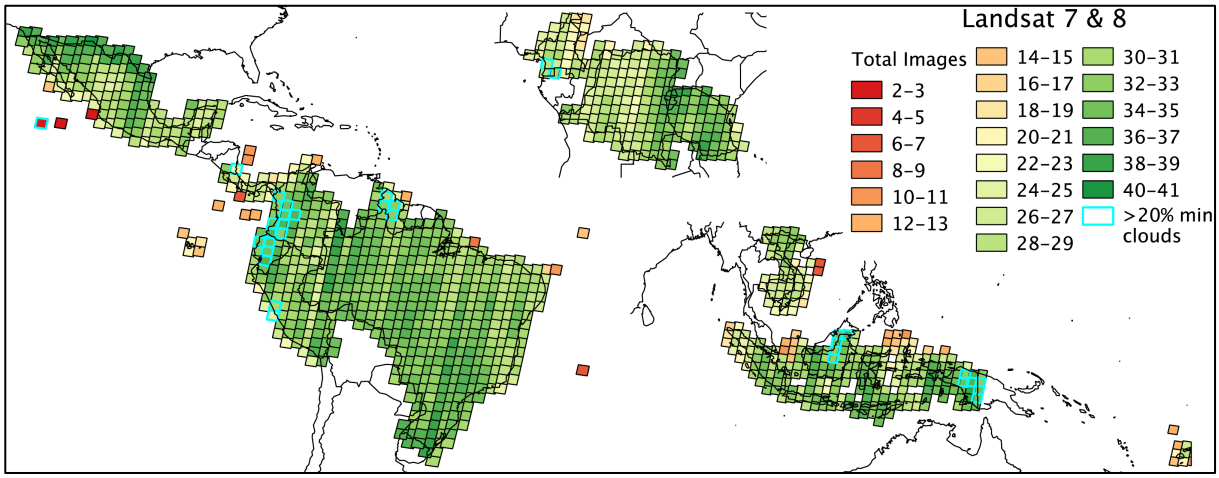


Figure 2.7. Maps of the number of images per path/row.

Table 2.4. The values in the table are the per cent cloud cover for Landsat 7 only, Landsat 8 only, and both Landsat 7 and 8 from the cumulative distribution at the 10% quantiles.

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Landsat 7 & 8	0.0	0.0	0.0	0.0	0.02	0.21	0.71	2.95	5.87	9.79	42.42
Landsat 7	0.0	0.0	0.0	0.0	0.1	0.38	2.48	5.75	9.57	15.62	53.1
Landsat 8	0.0	0.0	0.0	0.07	0.56	2.01	3.72	6.48	9.99	16.83	68.95

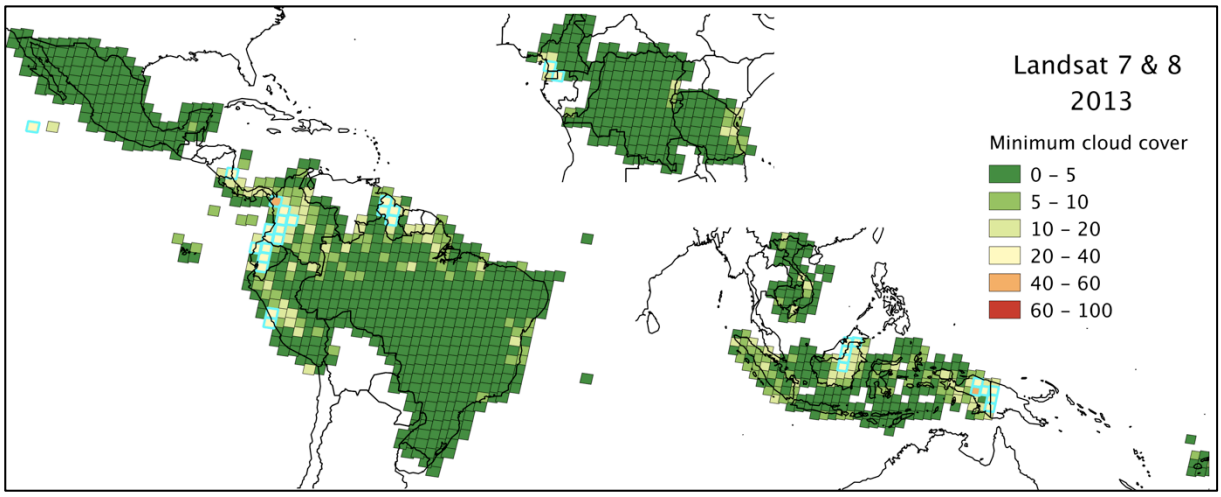


Figure 2.8. Maps of the distribution of the least cloudy images.

The 2013 requirement for cloud free data cannot be fully met solely with Landsat data. For all but a few path/rows, it should be possible to get cloud free estimates of the Earth's surface using more than one image. The statistics and the spatial distribution will continue to improve as data continue to be collected. The joint distributions of Landsat 7 and 8 show the result of changing from a 16-day to an 8-day repeat cycle. The inclusion of the Sentinel and CBERS-4 satellites foreseen in 2015 should show a corresponding improvement, once data from these sensors become available. But even with more optical sensors, some persistently cloudy locations will exist where multiple dates of optical images in themselves will be not be sufficient to yield cloud free looks at the Earth. Other sensors, such as SAR, will be required.

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 is:

- working to ensure continuity of coverage of the Forest Carbon Tracking (FCT) National Demonstrator countries and adds as a priority those countries that are seeking active participation in GFOI and have engaged in related capacity building activities;
- dependent on the launch of the core data streams anticipated between 2013 and 2016 and generally consistent with their acquisition capacities; these are:
    - INPE/CRESDA CBERS-4 (December 2014);
    - ESA Sentinel-1A and -1B (April 2014, late 2015);
    - ESA Sentinel-2A and -2B (Spring 2015, 2016);
    - CONAE/ASI SAOCOM-1A and -1B (2015, 2016)

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 National Data Requirements and Availability

The requirements for the baseline global data acquisition strategy can be anticipated to evolve continuously as the policy, methodological and reporting framework evolves. The acquisition plans and data access policies will also evolve as the provider space agency and user national data evolve.

Year	Country	Total number of images	Number of scenes	Number of scenes with less then 20% cloud cover	Number of scenes with less then 60% cloud cover
2013	Brazil	13101	392	390	392
	Cambodia	460	17	17	17
	Cameroon	949	37	35	37
	Colombia	2152	70	62	70
	Costa Rica	208	9	8	9
	Democratic Republic of the Congo	3542	119	119	119
	Ecuador	688	22	17	22
	Guyana	590	19	15	19
	Indonesia	6781	219	208	219
	Mexico	5025	156	155	156
	Nepal	618	19	19	19
	Panama	329	13	12	13
	Peru	2459	77	75	77
	United Republic of Tanzania	1669	49	49	49
	Viet Nam	1113	41	41	41

Table 3.1– Countries involved in the CEOS GFOI implementation. Reported are the total number of images; the number of scenes (Landsat WRS-2 path/rows); the number of scenes where the lowest cloud cover image has less than 20% cloud cover; and the number of scenes where the lowest cloud cover image has less than 60% cloud cover.

Summary statistics and maps describing the distribution of Landsat data are provided for each country. The statistics are the combined Landsat 7 & 8 statistics. The statistics for the first quarter (Jan-Mar) are biased low, since Landsat 8 did not begin nominal data acquisition until 15 April 2013. The estimates for Landsat 7 do not compensate for the 22% data loss due to the Scan Line Corrector failure in 2003. The middle 22 km of the image has no data loss. On the edge of the scene the data loss is approximately 50%.

About 41 total Landsat 7 & 8 images visits for each path row occurred in 2013 (23 for Landsat 7 and 18 for Landsat 8). By quarter for every path/row, there were 5-6 Landsat 7 visits in Jan-Mar; 5-6 Landsat 7 and 4-5 Landsat 8 visits in Apr-Jun (Landsat began acquisition of nominal data on 15 April 2013); and 5-6 visits for Landsat 7 and 8 in Jul-Sep and Oct-Dec. In 2013 Oct-Dec consistently showed the greatest number of acquisitions. This is a function of increased Landsat 7 acquisition rates in November 2013, the 15 April start date for Landsat 8, and reduced competition with northern growing season acquisitions.

3.1 Brazil

A 392 scene annual mosaic of the least cloudy Landsat images for Brazil in 2013 will contain 50% cloud-free path/rows (Figure 3.1). The worst path/row had 33% cloud cover. For 15 path/rows, the best cloud cover is greater than 10% (Table 3.2). Two path/rows (1%) had cloud cover greater than 20%. By quarter, Jul-Sep has the most path/rows (328) with less than 10% cloud cover, while Jan-Mar has the fewest (111). A total of 13,101 images were acquired (Table 3.3). 362 path/rows (92%) had 30 or more observations. Only 8 path/rows had fewer than 18 observations.

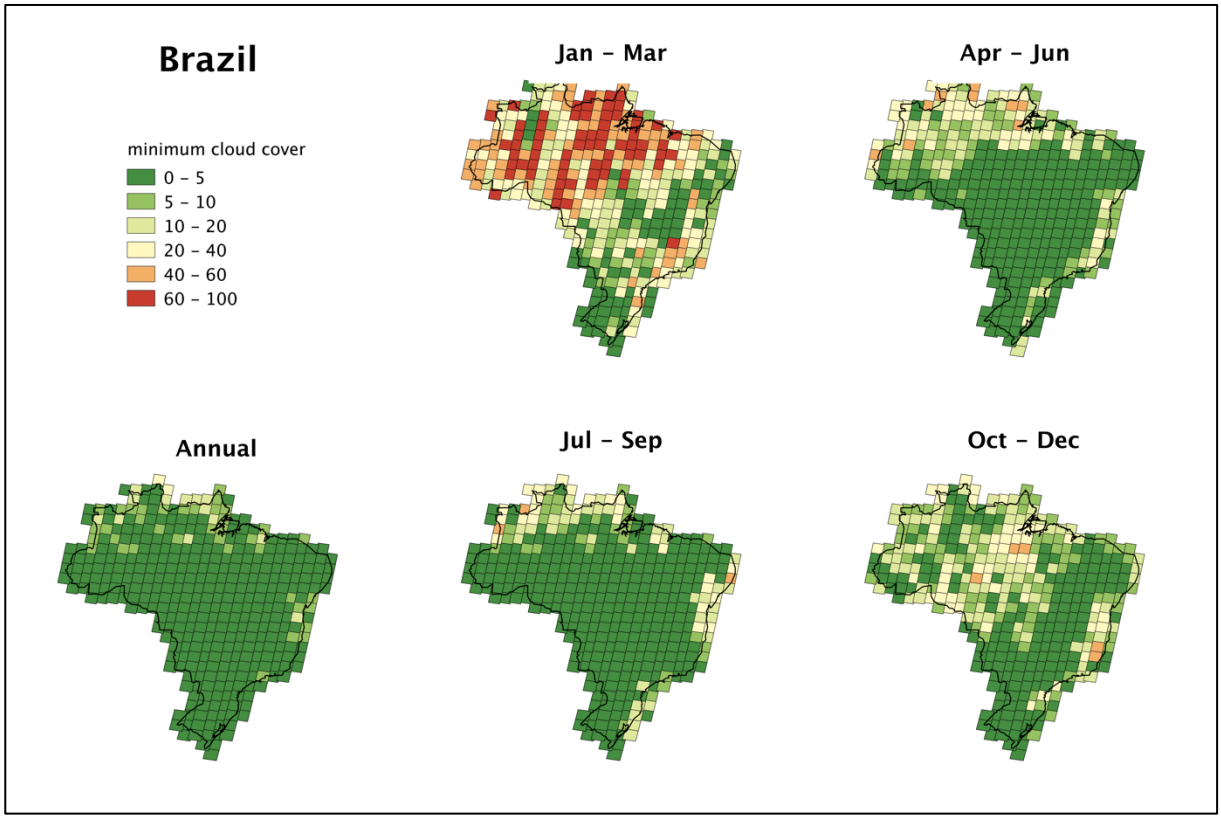


Figure 3.1. The spatial distribution of least cloudy data by season

Table 3.2. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	377	13	1	1	0	0	0	0	0	0
Jan-Mar	111	65	45	31	33	39	24	22	15	6
Apr-Jun	295	49	20	19	4	5	0	0	0	0
Jul-Sep	328	35	18	7	3	0	0	0	0	0
Oct-Dec	262	78	36	11	4	1	0	0	0	0

Table 3.3. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	13101	0	0	0	1	1	0	1	1	1	0	0	0	0	3	22	54	81	139	67	21
Jan-Mar	1789	5	67	235	84	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	3275	0	3	23	93	157	116	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	3934	1	0	3	7	116	223	41	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	4103	0	2	2	1	59	259	69	0	0	0	0	0	0	0	0	0	0	0	0	0

3.2 Cambodia

A 17 scene annual mosaic (Figure 3.2) of the least cloudy Landsat images for Cambodia in 2013 will contain 10% cloud free scenes, 60% of the scenes with less than 1% cloud cover, and all of the scenes with better than 18% cloud cover. The worst path/row will have 18% cloud cover (Table 3.4). No path/row had cloud cover greater than 20%. By quarter, Oct-Dec and Jan-Mar have the least cloudy images, while Jul-Sep has the most. The scenes are selected from a total of 460 images (Table 3.6). Two path/rows (12%) had 30 or more observations. No path/row had fewer than 20 observations.

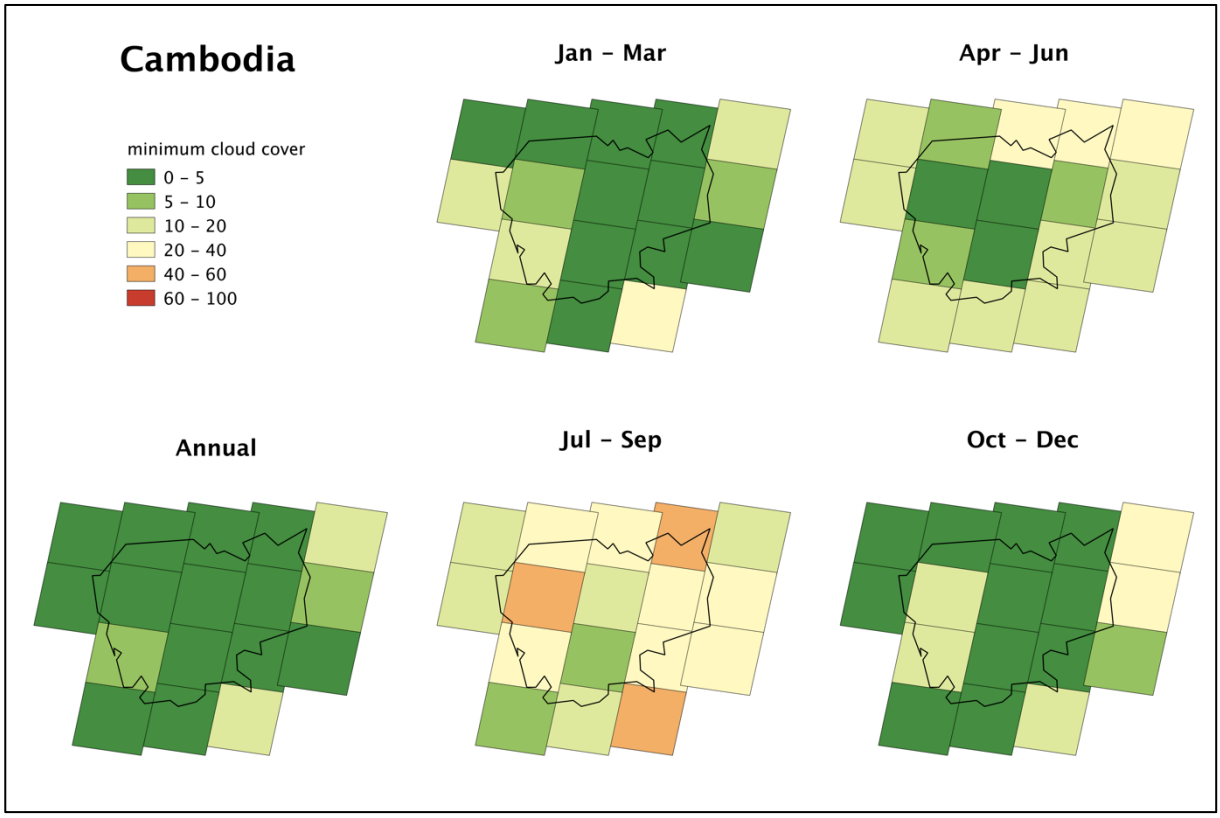


Figure 3.2. The spatial distribution of least cloudy data by season

Table 3.4. The number of path/rows in the mosaic by number of images per path/row (columns)

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	15	2	0	0	0	0	0	0	0	0
Jan-Mar	13	3	1	0	0	0	0	0	0	0
Apr-Jun	6	8	3	0	0	0	0	0	0	0
Jul-Sep	2	5	4	3	3	0	0	0	0	0
Oct-Dec	12	3	1	1	0	0	0	0	0	0

Table 3.5. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	460	0	0	0	0	0	0	0	0	0	0	1	0	3	5	6	2	0	0	0	0
Jan-Mar	70	0	3	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	110	0	0	1	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	111	0	0	1	14	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	169	0	0	0	1	1	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.3 Cameroon

A 37 scene annual mosaic (Figure 3.3) of the least cloudy Landsat images for Cameroon in 2013 will contain 60% cloud-free scenes, 80% of the scenes with less than 1% cloud cover, and 90% of the scenes with less than 12% cloud cover. The worst path/row had 33% cloud cover (Table 3.6). Two path/rows (5%) had cloud cover greater than 20%. By quarter, Oct-Dec has the least cloudy images, while Jul-Sep has the most. The scenes are selected from a total of 949 images (Table 3.7). Seven path/rows (25%) had 30 or more observations. No path/rows had fewer than 18 observations.

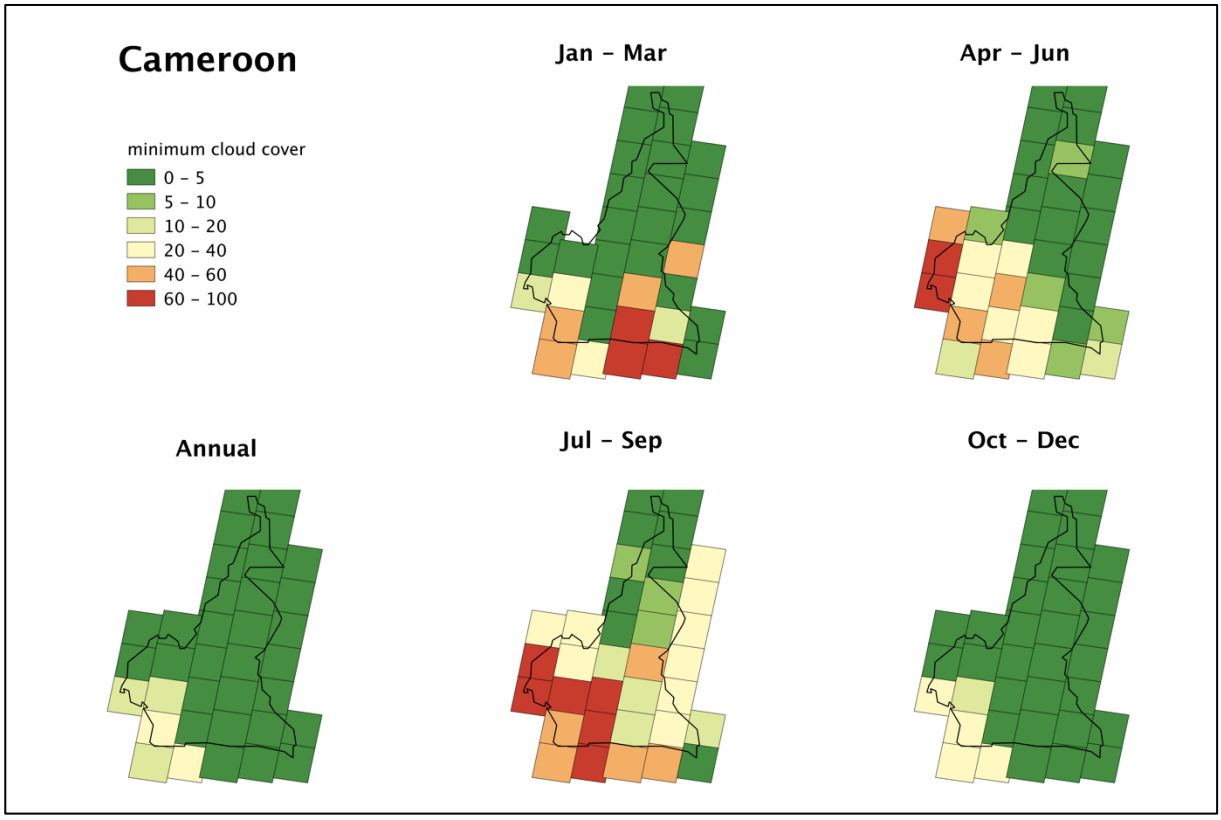


Figure 3.3. The spatial distribution of least cloudy data by season

Table 3.6. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	32	3	0	2	0	0	0	0	0	0
Jan-Mar	24	2	0	2	2	2	1	2	0	0
Apr-Jun	22	2	5	2	3	1	2	0	0	0
Jul-Sep	11	4	3	7	2	4	3	1	2	0
Oct-Dec	32	1	2	2	0	0	0	0	0	0

Table 3.7. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	949	0	0	0	0	0	0	0	0	0	3	3	3	10	6	5	5	2	0	0	0
Jan-Mar	114	2	18	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	221	0	1	16	14	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	264	0	0	2	23	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	350	0	0	0	3	14	19	1	0	0	0	0	0	0	0	0	0	0	0	0	0

3.4 Colombia

A 71 scene annual mosaic (Figure 3.4) of the least cloudy Landsat images for Colombia in 2013 will contain no cloud-free scenes, 20% of the scenes with less than 1% cloud cover, 70% of the scenes with less than 11% cloud cover, and 90% of the scenes with less than 21% cloud cover. The worst path/row had 41% cloud cover (Table 3.8). Eight path/rows (11%) had cloud cover greater than 20%. By quarter, Jan-Mar has the least cloud images, while Apr-Jun has the most. The scenes are selected from a total of 2152 images (Table 3.9). 46 path/rows (65%) had 30 or more observations. Only 5 path/rows had 20 or fewer observations.

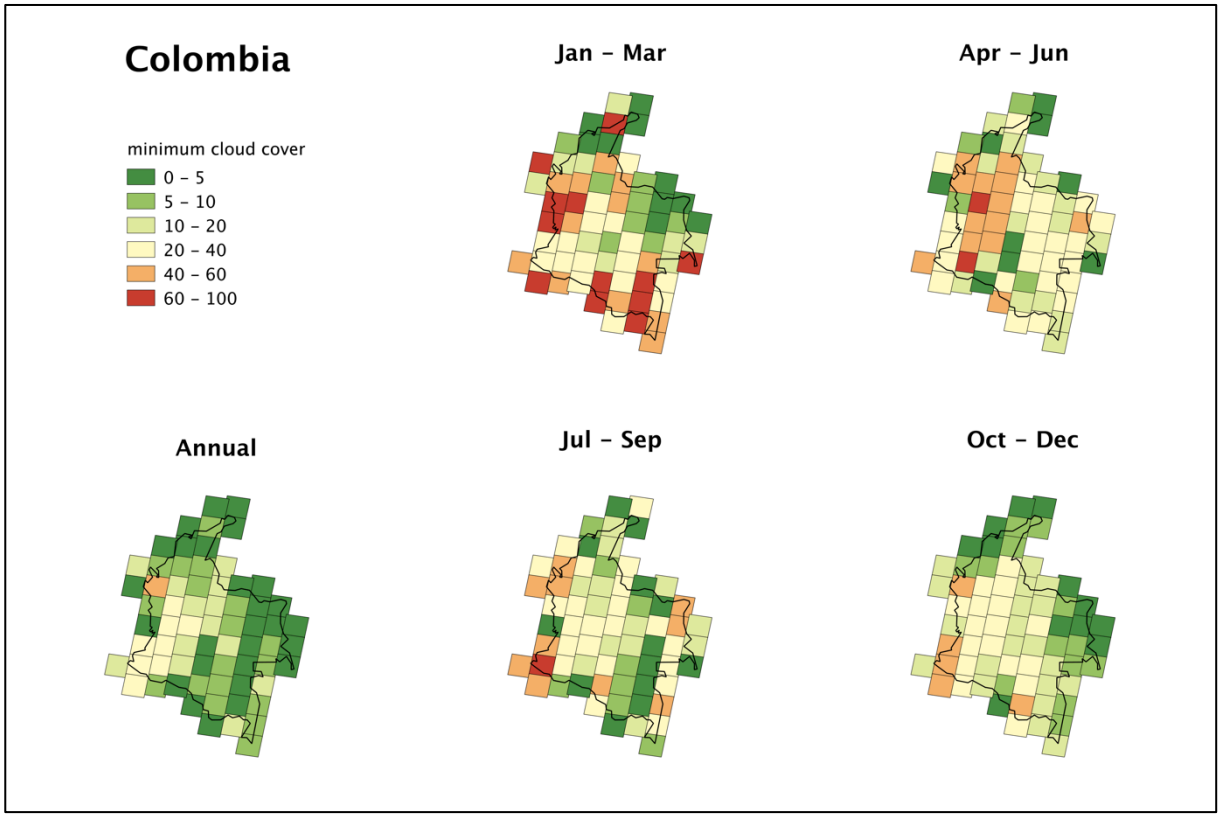


Figure 3.4. The spatial distribution of least cloudy data by season

Table 3.8. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	50	13	3	4	1	0	0	0	0	0
Jan-Mar	21	10	7	10	5	7	3	3	5	0
Apr-Jun	14	16	7	17	11	4	2	0	0	0
Jul-Sep	22	13	15	9	4	6	2	0	0	0
Oct-Dec	27	21	7	12	4	0	0	0	0	0

Table 3.9. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	2174	0	0	0	0	0	2	1	2	0	0	0	4	3	4	9	7	5	20	7	7
Jan-Mar	302	4	11	48	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	522	0	5	12	18	20	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	616	3	1	4	14	14	31	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	734	0	0	2	3	7	46	13	0	0	0	0	0	0	0	0	0	0	0	0	0

3.5 Costa Rica

A 9 scene annual mosaic (Figure 3.5) of the least cloudy Landsat images for Costa Rica in 2013 will contain no cloud-free scenes, and 50% of the scenes with less than 10% cloud cover. The worst path/row will have 26% cloud cover (Table 3.10). One path/rows (11%) had cloud cover greater than 20%. By quarter, Jan-Mar has the least cloudy images, while Apr-Jun and Jul-Sep have the most. The scenes are selected from a total of 208 images (Table 3.11). Two path/rows (22%) had 30 or more observations. Two path/rows had fewer than 22 observations.

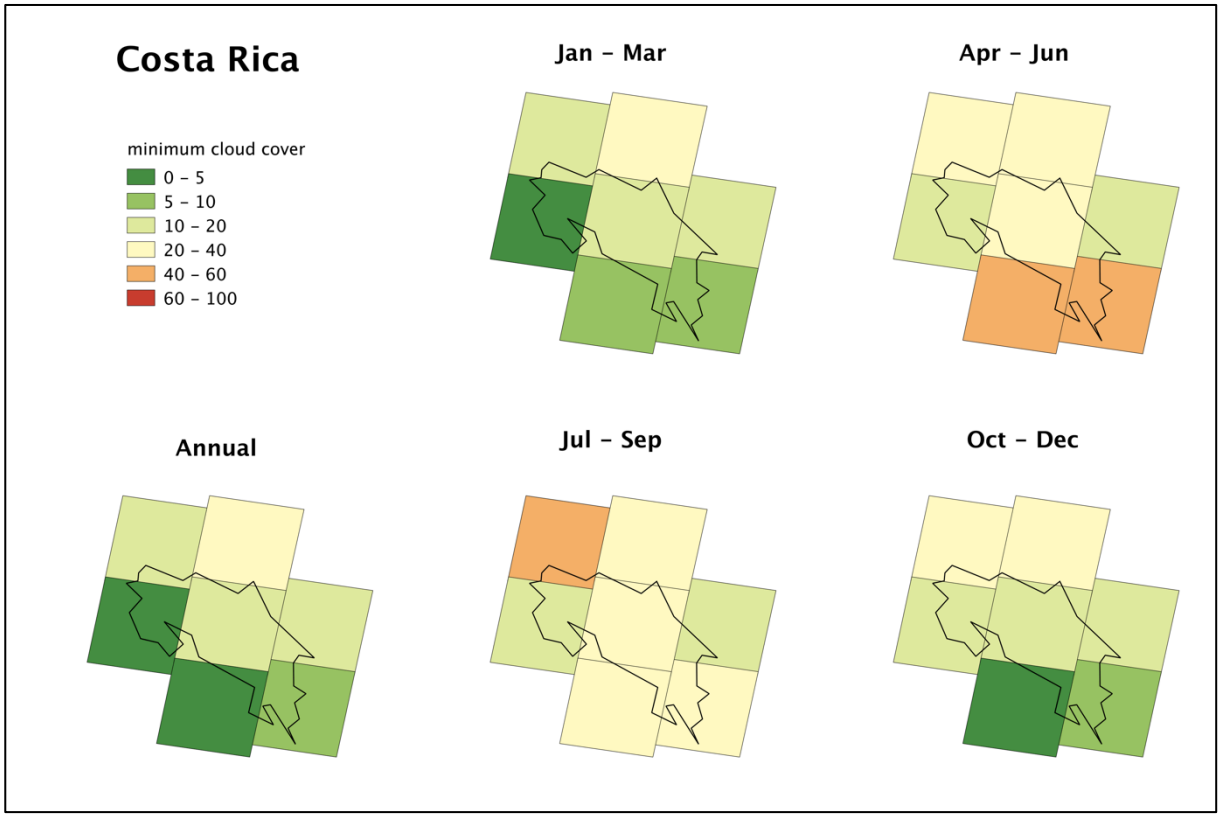


Figure 3.5. The spatial distribution of least cloudy data by season

Table 3.10. The number of path/rows in the mosaic by number of images per path/row (columns)

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	5	3	1	0	0	0	0	0	0	0
Jan-Mar	4	3	1	0	0	0	0	0	0	0
Apr-Jun	0	2	1	3	2	1	0	0	0	0
Jul-Sep	0	2	4	0	1	2	0	0	0	0
Oct-Dec	3	3	1	2	0	0	0	0	0	0

Table 3.11. The distribution of the number of images per path/row

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	208	0	0	0	1	0	0	0	1	0	0	0	2	1	2	0	1	1	0	0	0
Jan-Mar	29	0	3	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	41	2	0	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	58	1	0	2	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	80	0	0	1	1	2	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.6 Democratic Republic of the Congo

A 119 scene annual mosaic (Figure 3.6) of the least cloudy Landsat images for Colombia in 2013 will contain 50% cloud-free scenes, and 90% of the scenes with less than 1% cloud cover. The worst path/row had 10% cloud cover (Table 3.12). No path/row had cloud cover greater than 20%. By quarter, Apr-Jun has the least cloudy images, while Jan-Mar has the most. The scenes are selected from a total of 3542 images (Table 3.13). 55 path/rows (46%) has 30 or more observations. No path/rows has fewer than 21 observations.

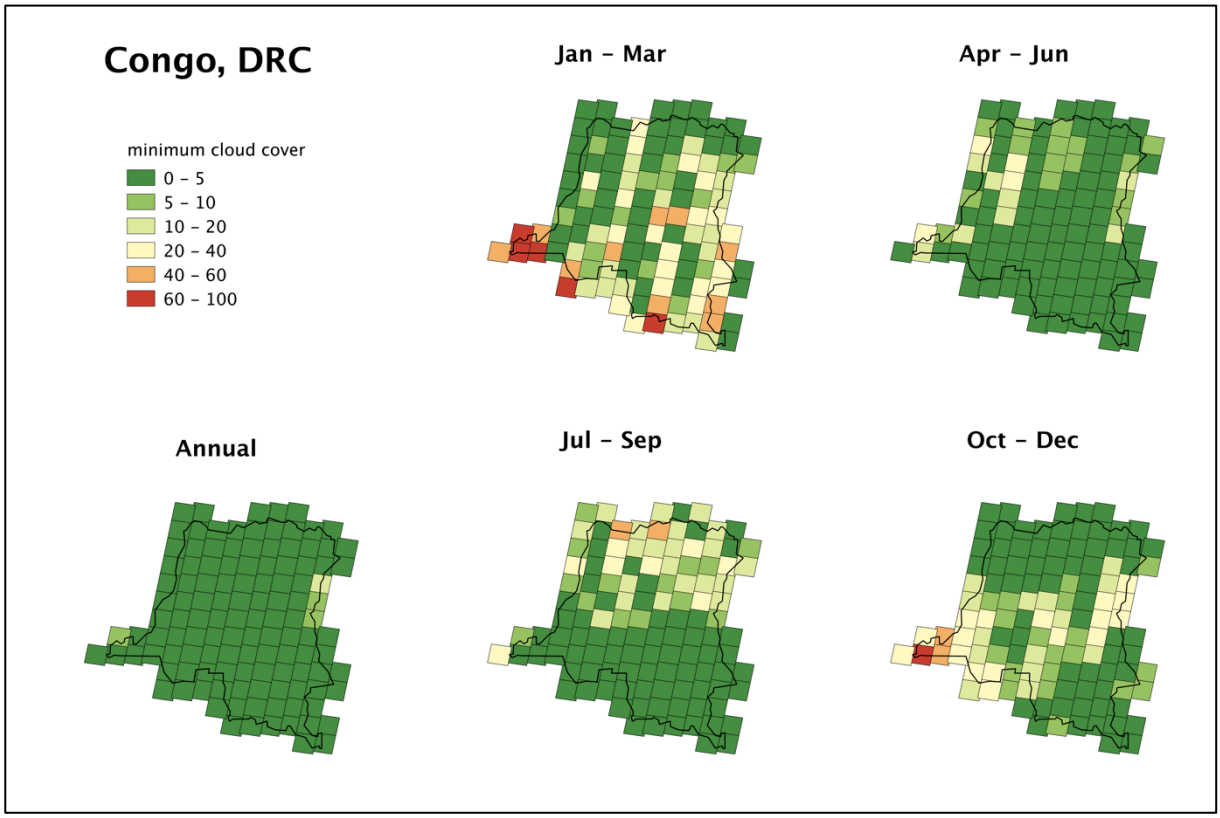


Figure 3.6. The spatial distribution of least cloudy data by season

Table 3.12. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	118	1	0	0	0	0	0	0	0	0
Jan-Mar	66	19	11	9	3	6	3	2	0	0
Apr-Jun	107	8	2	2	0	0	0	0	0	0
Jul-Sep	89	21	5	2	2	0	0	0	0	0
Oct-Dec	86	13	14	3	2	0	1	0	0	0

Table 3.13. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	3542	0	0	0	0	0	0	0	0	0	0	1	1	9	32	21	20	6	21	7	1
Jan-Mar	594	1	5	87	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	856	0	1	12	60	35	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	954	0	0	5	45	41	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	1138	0	0	0	10	48	45	16	0	0	0	0	0	0	0	0	0	0	0	0	0

3.7 Ecuador

A 22 scene annual mosaic (Figure 3.7) of the least cloudy Landsat images for Ecuador in 2013 will contain no cloud free scenes, 20% of the scenes with less than 1% cloud cover, and 60% of the scenes with less than 10% cloud cover. The worst path/row will have 40% cloud cover (Table 3.14). By quarter, Apr-Jun and Jul-Sep have the most cloud free images, while Jan-Mar has the fewest. The scenes are selected from a total of 688 images (Table 3.15). 18 path/rows (82%) had 30 or more observations. No path/row had fewer than 28 observations. Five path/rows (23%) had cloud cover greater than 20%.

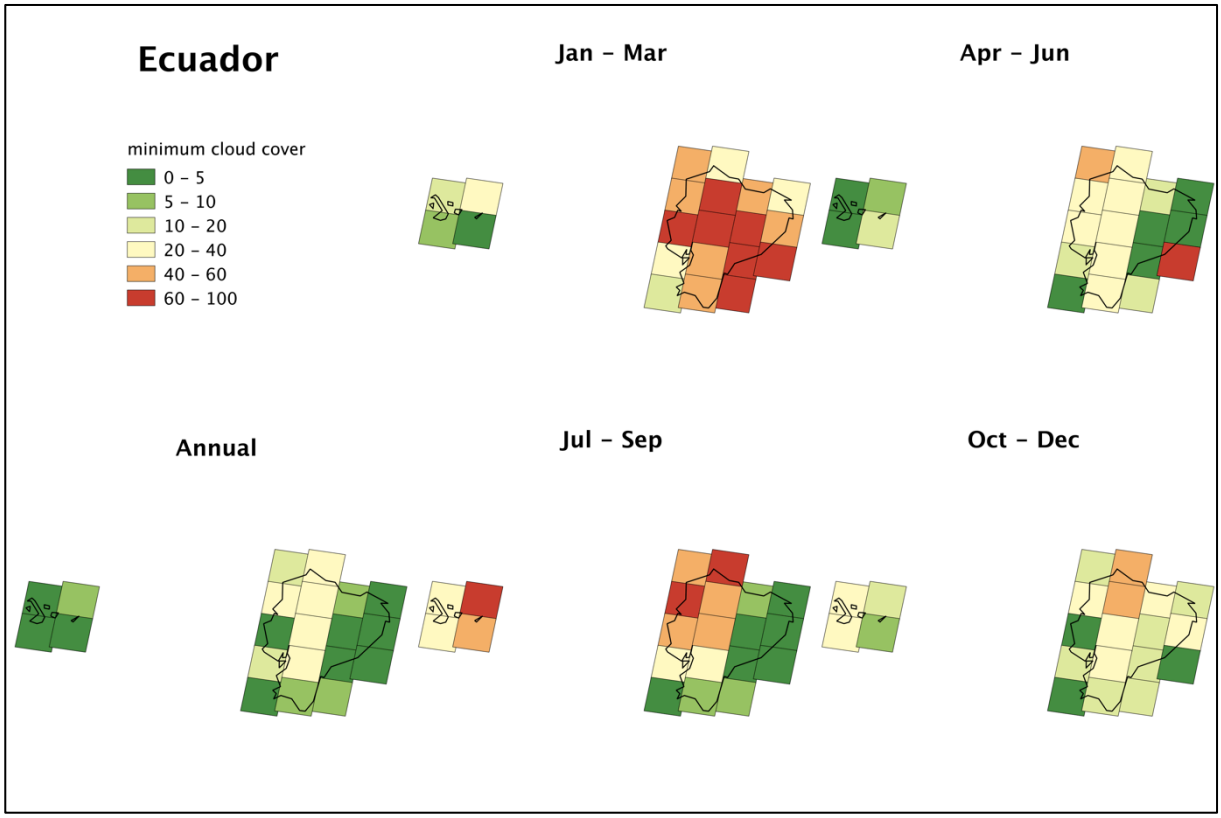


Figure 3.7. The spatial distribution of least cloudy data by season

Table 3.14. The number of path/rows in the mosaic by number of images per path/row (columns)

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	15	2	3	2	0	0	0	0	0	0
Jan-Mar	3	2	2	2	3	3	0	4	2	1
Apr-Jun	8	4	3	4	2	0	0	0	1	0
Jul-Sep	9	0	1	4	1	4	1	2	0	0
Oct-Dec	4	8	3	4	2	1	0	0	0	0

Table 3.15. The distribution of the number of images per path/row

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	688	0	0	0	0	0	0	0	1	1	1	0	2	0	0	0	1	3	5	6	2
Jan-Mar	93	0	5	17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	192	0	1	2	4	3	11	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	188	0	2	3	0	6	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	215	0	1	1	3	2	7	8	0	0	0	0	0	0	0	0	0	0	0	0	0

3.8 Guyana

A 18 scene annual mosaic (Figure 3.8) of the least cloudy Landsat images for Guyana in 2013 will contain no cloud-free scenes, 30% of the scenes with less than 5% cloud cover, and 90% of the scenes with less than 26% cloud cover. The worst path/row will have 33% cloud cover (Table 3.16). Four path/rows (22%) had cloud cover greater than 20%. By quarter, Jul-Sep and Oct-Dec have slightly less cloudy images, while Jan-Mar has the most. The scenes are selected from a total of 554 images (Table 3.17). 14 path/rows (78%) had 30 or more observations. Only one path/row had fewer than 26 observations.

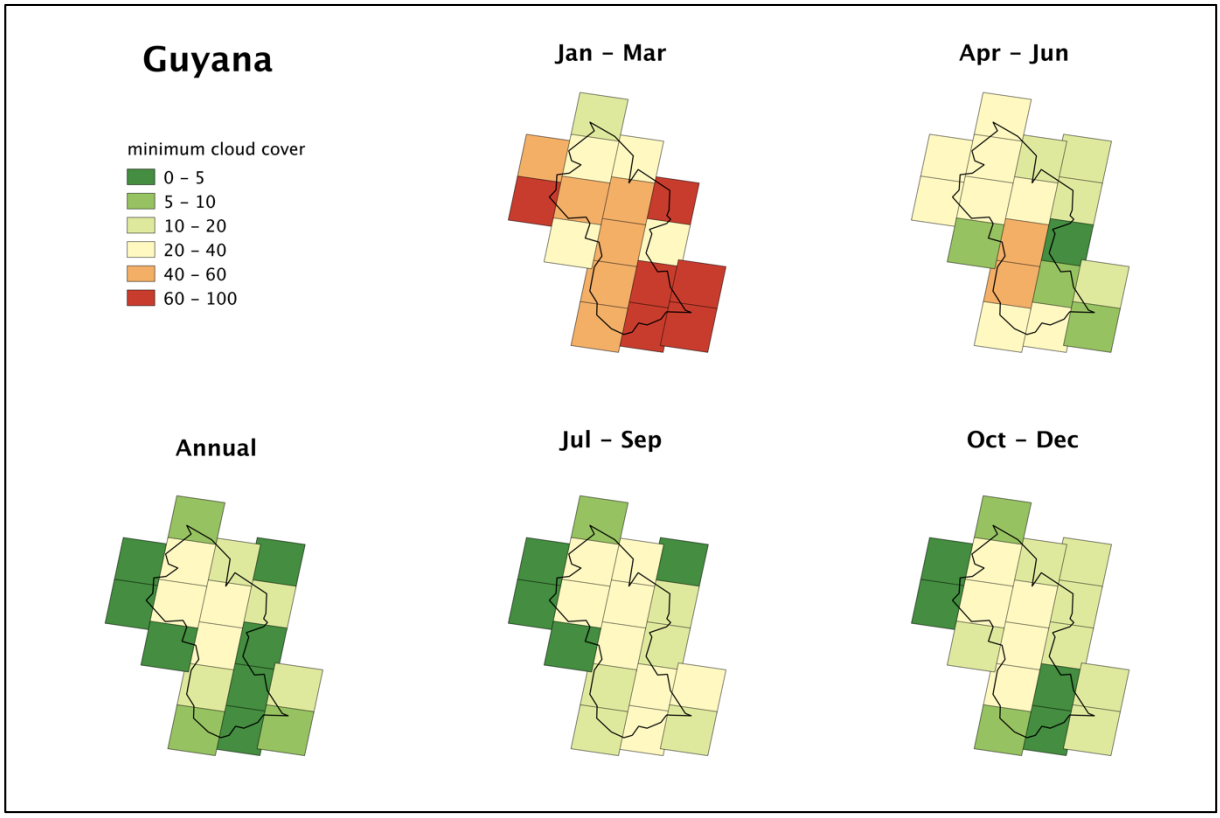


Figure 3.8. The spatial distribution of least cloudy data by season

Table 3.16. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	10	4	3	1	0	0	0	0	0	0
Jan-Mar	0	1	2	2	4	2	3	1	2	0
Apr-Jun	4	4	2	6	0	2	0	0	0	0
Jul-Sep	5	5	6	2	0	0	0	0	0	0
Oct-Dec	6	7	3	2	0	0	0	0	0	0

Table 3.17. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	554	0	0	0	0	0	0	0	1	0	0	0	0	0	2	1	4	3	7	0	0
Jan-Mar	72	1	3	11	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	147	0	0	1	6	7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	168	0	0	0	2	5	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	167	0	0	1	3	1	13	0	0	0	0	0	0	0	0	0	0	0	0	0	0

3.9 Indonesia

A 219 scene annual mosaic (Figure 3.9) of the least cloudy Landsat images for Indonesia in 2013 will contain less than 10% cloud-free scenes, 20% of the scenes with less than 1% cloud cover, and 80% of the scenes with less than 10% cloud cover. The worst path/row will have 42% cloud cover (Table 3.18). Eleven path/rows (5%) had cloud cover greater than 20%. By quarter, Apr-Jun has the least cloudy images, while Jan-Mar has the most. The scenes are selected from a total of 6781 images (Table 3.19). 149 path/rows (68%) had 30 or more observations. Only one path/row had fewer than 10 observations.

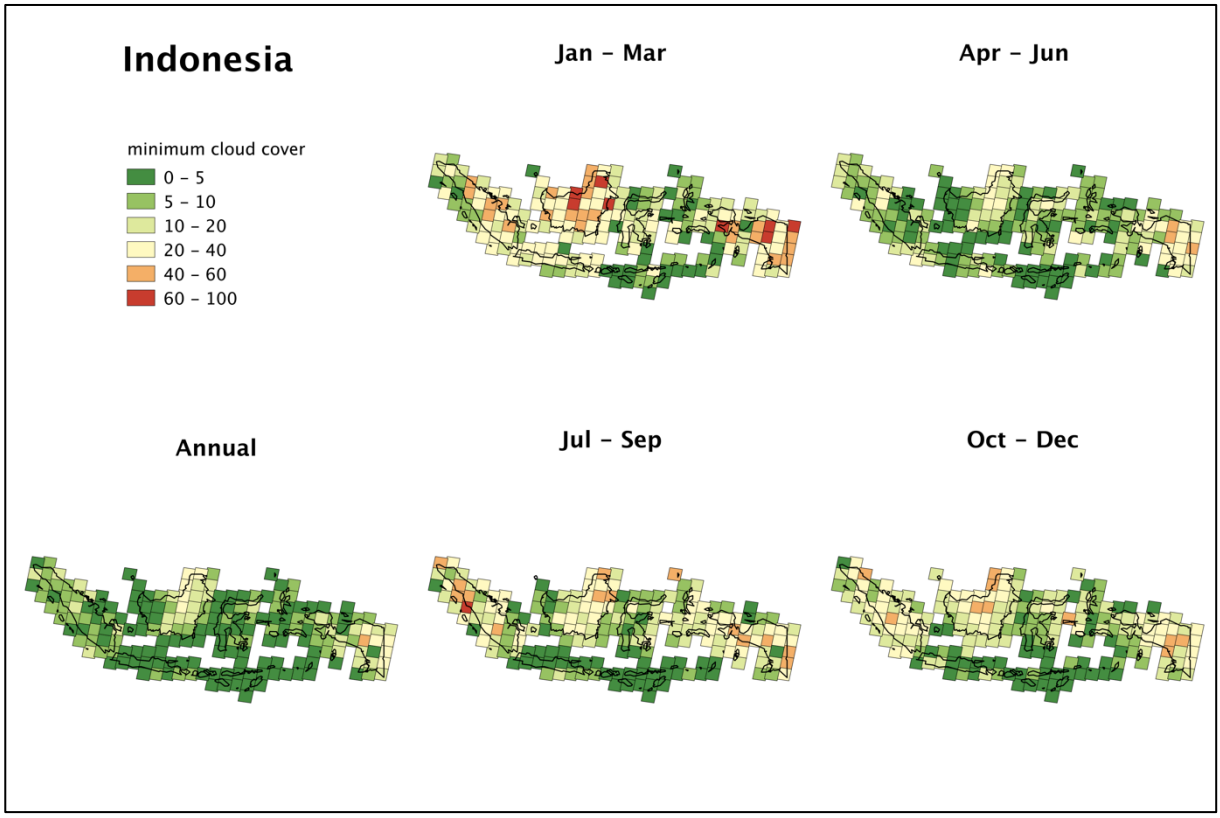


Figure 3.9. The spatial distribution of least cloudy data by season

Table 3.18. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	180	29	8	2	1	0	0	0	0	0
Jan-Mar	72	49	42	25	18	5	5	1	1	1
Apr-Jun	145	40	21	9	4	0	0	0	0	0
Jul-Sep	103	47	27	23	9	6	3	0	0	0
Oct-Dec	97	68	32	13	8	2	0	0	0	0

Table 3.19. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	6784	0	1	0	0	0	1	2	5	4	3	6	0	10	18	21	14	45	49	27	14
Jan-Mar	1106	2	13	119	85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	1782	1	5	20	42	89	62	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	1931	5	7	8	44	46	79	29	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	1965	0	3	9	29	84	85	10	0	0	0	0	0	0	0	0	0	0	0	0	0

3.10 Mexico

A 156 scene annual mosaic (Figure 3.10) of the least cloudy Landsat images for Mexico in 2013 will contain 70% cloud-free scenes, and 90% of the scenes with less than 1% cloud cover. The worst path/row will have 39% cloud cover (Table 3.20). One path/rows (1%) had cloud cover greater than 20%. By quarter, Jan-Mar and Oct-Dec have least cloudy images, while Jul-Sep has most. The scenes are selected from a total of 5025 images (Table 3.21). 104 path/rows (67%) had 30 or more observations. No path/rows had fewer than 21 observations.

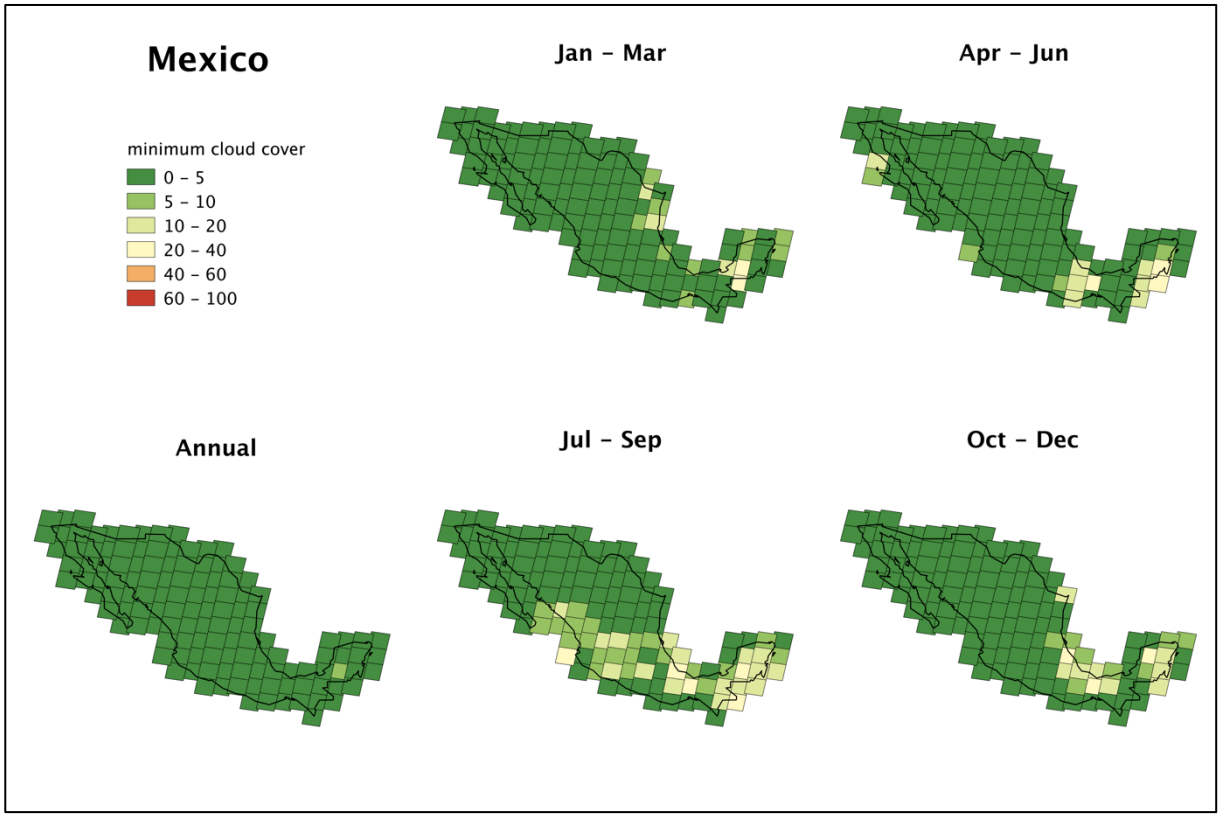


Figure 3.10. The spatial distribution of least cloudy data by season

Table 3.20. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	154	1	0	1	0	0	0	0	0	0
Jan-Mar	143	7	2	1	1	0	0	0	0	0
Apr-Jun	143	6	1	2	0	0	0	2	0	0
Jul-Sep	133	16	4	1	0	0	0	0	0	0
Oct-Dec	143	9	1	3	0	0	0	0	0	0

Table 3.21. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	5025	0	2	1	0	0	0	1	0	2	0	0	1	7	16	18	23	10	14	17	40
Jan-Mar	713	1	31	76	46	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	1284	1	6	11	31	53	48	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	1451	1	1	4	20	46	60	22	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	1577	0	4	2	6	30	80	34	0	0	0	0	0	0	0	0	0	0	0	0	0

3.11 Nepal

A 19 scene annual mosaic (Figure 3.11) of the least cloudy Landsat images for Nepal in 2013 will contain 30% cloud-free scenes, and 50% of the scenes with less than 1% cloud cover. The worst path/row will have 4% cloud cover (Table 3.22). No path/row had cloud cover greater than 20%. By quarter, Oct-Dec has the least cloudy images, while Jul-Sep has the most. The scenes are selected from a total of 618 images (Table 3.23). 18 path/rows (95%) had 30 or more observations. No path/row had fewer than 28 observations.

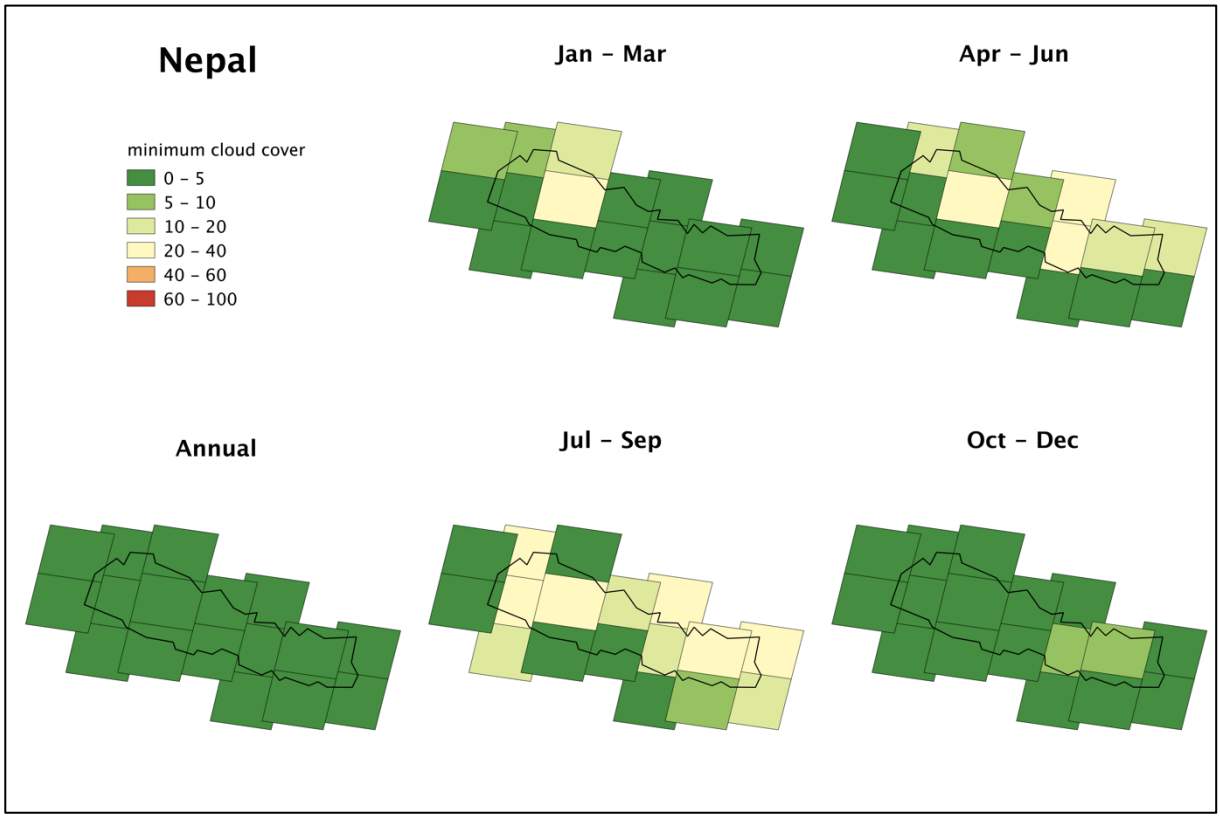


Figure 3.11. The spatial distribution of least cloudy data by season

Table 3.22. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	19	0	0	0	0	0	0	0	0	0
Jan-Mar	17	1	1	0	0	0	0	0	0	0
Apr-Jun	13	3	2	1	0	0	0	0	0	0
Jul-Sep	7	4	6	2	0	0	0	0	0	0
Oct-Dec	19	0	0	0	0	0	0	0	0	0

Table 3.23. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	618	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	6	5	2	0
Jan-Mar	82	0	2	16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	162	0	0	2	1	9	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	168	0	0	0	4	9	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	206	0	0	0	0	0	17	2	0	0	0	0	0	0	0	0	0	0	0	0	0

3.12 Panama

A 13 scene annual mosaic (Figure 3.12) of the least cloudy Landsat images for Panama in 2013 will contain no cloud free scenes, 10% of the scenes with less than 1% cloud cover, and 60% of the scenes with less than 10% cloud cover. The worst path/row has 41% cloud cover (Table 3.24). One path/row (8%) had cloud cover greater than 20%. By quarter, Oct-Dec has the least cloudy images, while Apr-Jun and Jul-Sep have the most. The scenes are selected from a total of 688 images (Table 3.25). Two path/rows (15%) had 30 or more observations. One path/row had fewer than 20 observations.

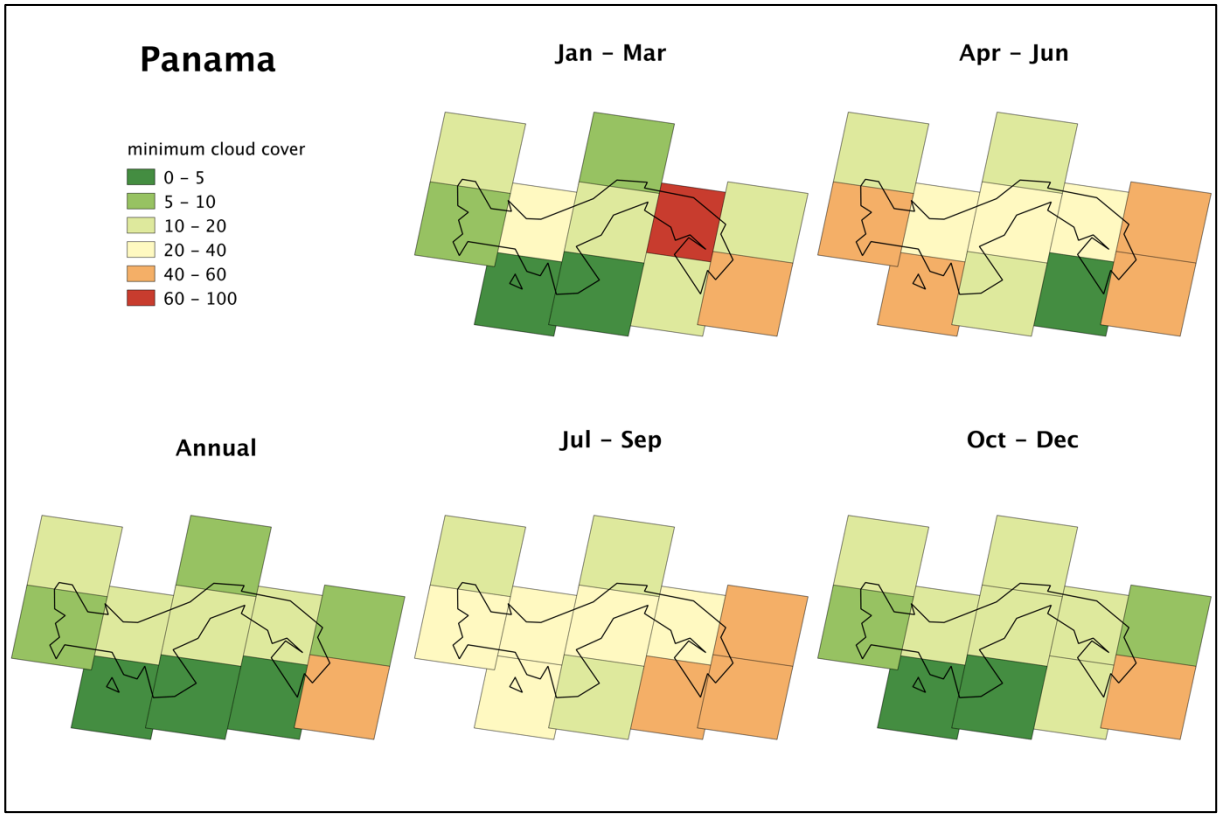


Figure 3.12. The spatial distribution of least cloudy data by season

Table 3.24. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	8	4	0	0	1	0	0	0	0	0
Jan-Mar	4	4	1	0	0	2	0	1	0	0
Apr-Jun	2	3	1	2	4	1	0	0	0	0
Jul-Sep	1	3	3	2	0	4	0	0	0	0
Oct-Dec	6	6	0	0	1	0	0	0	0	0

Table 3.25. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	329	0	0	0	1	0	0	0	0	0	0	1	1	3	1	4	0	1	1	0	0
Jan-Mar	39	3	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	65	1	1	6	4	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	87	1	0	1	7	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	138	0	0	1	0	1	6	5	0	0	0	0	0	0	0	0	0	0	0	0	0

3.13 Peru

A 77 scene annual mosaic (Figure 3.13) of the least cloudy Landsat images for Peru in 2013 will contain 10% cloud-free scenes, and 50% of the scenes with less than 1% cloud cover. The worst path/row will have 21% cloud cover (Table 3.26). Two path/rows (3%) had cloud cover greater than 20%. By quarter, Jul-Sep has the most images with less than 10% cloud cover. Oct-Dec has no image with greater than 50% cloud cover. Jan-Mar has the most cloudy images. The scenes are selected from a total of 2459 images (Table 3.27). 59 path/rows (77%) had 30 or more observations. No path/row had fewer than 22 observations.

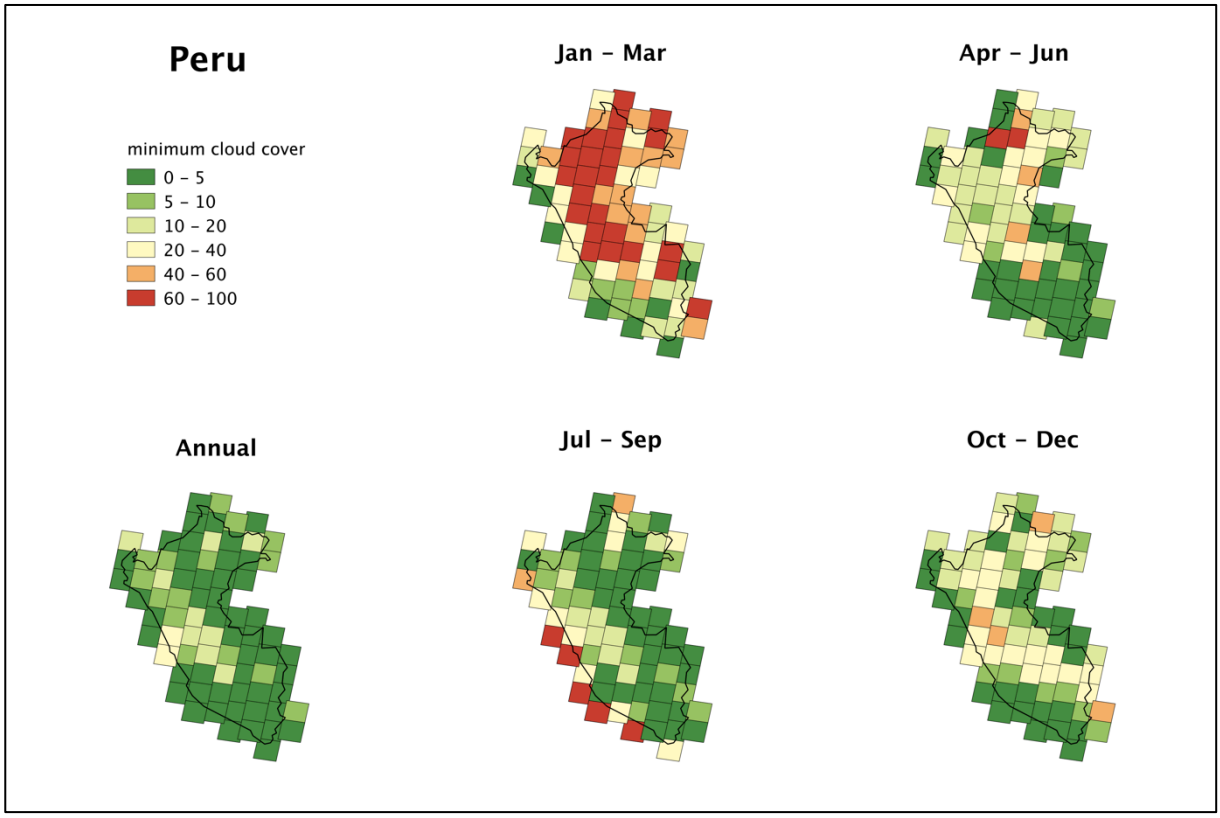


Figure 3.13. The spatial distribution of least cloudy data by season

Table 3.26. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	65	10	2	0	0	0	0	0	0	0
Jan-Mar	13	10	5	10	6	9	9	8	5	2
Apr-Jun	38	19	5	9	3	1	1	0	1	0
Jul-Sep	51	8	7	3	1	1	2	2	2	0
Oct-Dec	37	18	10	8	4	0	0	0	0	0

Table 3.27. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	2459	0	0	0	0	0	0	0	0	0	0	0	1	2	6	9	12	18	21	5	3
Jan-Mar	307	1	20	53	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	636	0	0	5	25	27	17	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	741	0	0	1	7	22	39	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	775	0	0	0	0	21	52	4	0	0	0	0	0	0	0	0	0	0	0	0	0

3.14 United Republic of Tanzania

A 49 scene annual mosaic (Figure 3.14) of the least cloudy Landsat images for Tanzania in 2013 will contain 30% cloud-free scenes, and 70% of the scenes with less than 1% cloud cover. The worst path/row will have 14% cloud cover (Table 3.28). No path/row had cloud cover greater than 20%. By quarter, Jul-Sep has the least cloudy images, while Jan-Mar has the most. The scenes are selected from a total of 2459 images (Table 3.29). 44 path/rows (90%) had 30 or more observations. No path/row had fewer than 24 observations.

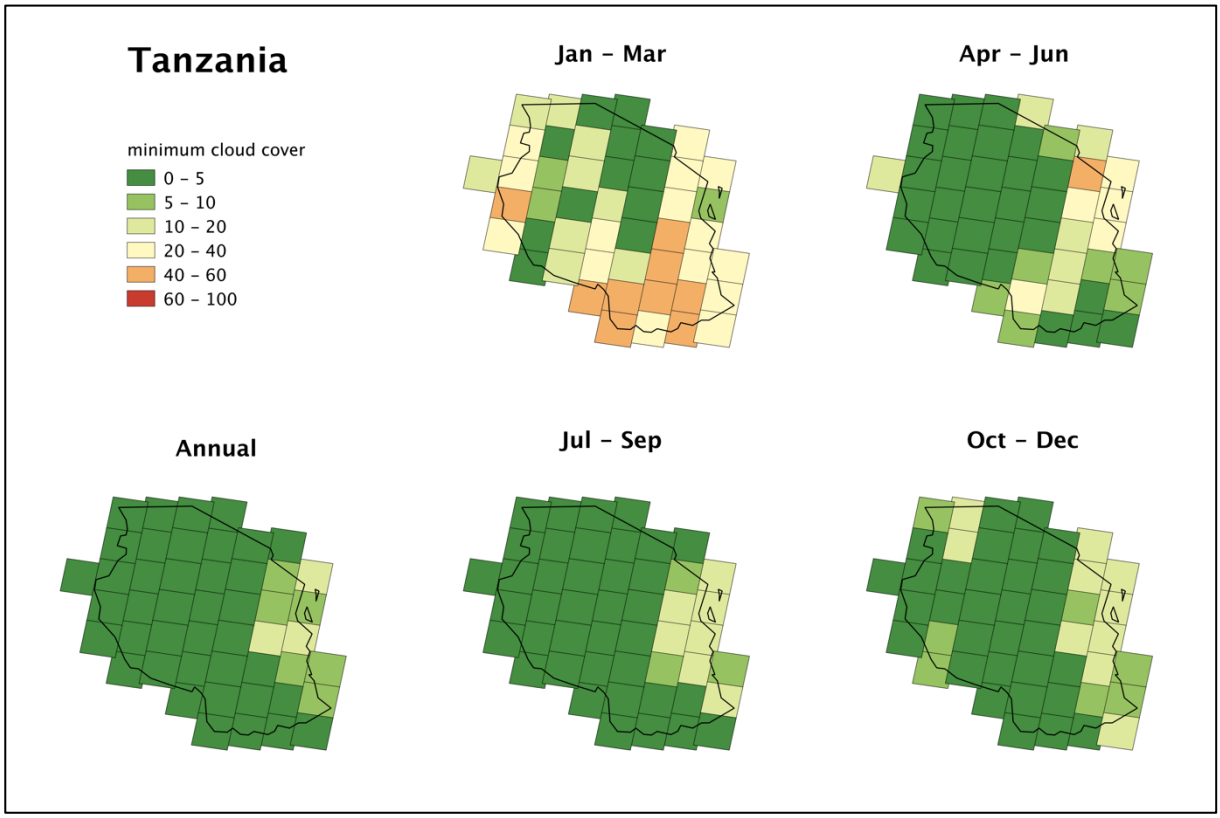


Figure 3.14. The spatial distribution of least cloudy data by season

Table 3.28. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	46	3	0	0	0	0	0	0	0	0
Jan-Mar	16	9	9	6	5	4	0	0	0	0
Apr-Jun	38	5	3	2	1	0	0	0	0	0
Jul-Sep	42	7	0	0	0	0	0	0	0	0
Oct-Dec	39	10	0	0	0	0	0	0	0	0

Table 3.29. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	1669	0	0	0	0	0	0	0	0	0	0	0	0	1	0	4	3	11	13	11	6
Jan-Mar	215	0	8	38	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	448	0	0	0	10	12	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	486	0	0	0	6	9	26	8	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	520	0	0	0	0	5	37	7	0	0	0	0	0	0	0	0	0	0	0	0	0

3.15 Viet Nam

A 41 scene annual mosaic (Figure 3.15) of the least cloudy Landsat images for Viet Nam in 2013 will contain 10% cloud free scenes, 70% of the scenes with less than 1% cloud cover, and 90% of the scenes with less than 10% cloud cover. The worst path/row has 17% cloud cover (Table 3.30). No path/row had cloud cover greater than 20%. By quarter, Oct-Dec has the least cloudy images, while Jul-Sep has the most. The scenes are selected from a total of 1113 images (Table 3.31). 13 path/rows (32%) had 30 or more observations. Two path/rows had fewer than 20 observations.

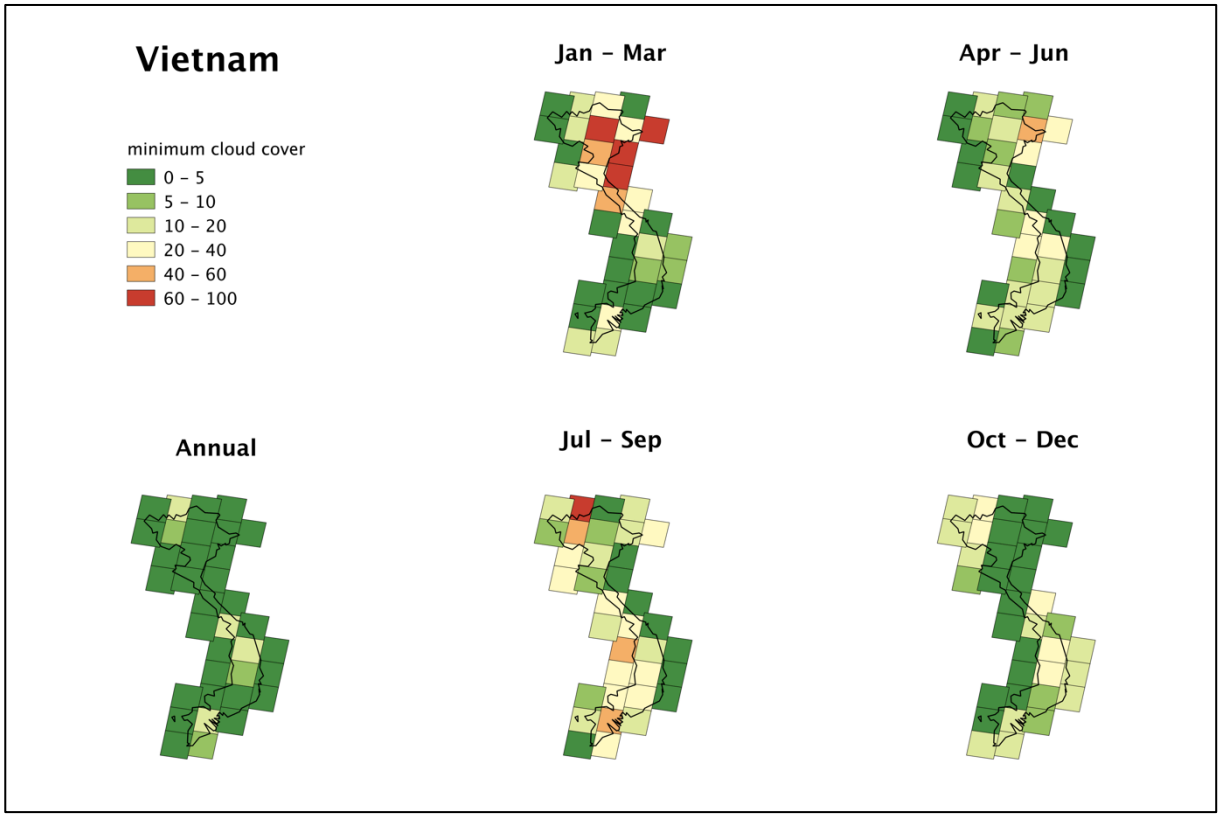


Figure 3.15. The spatial distribution of least cloudy data by season

Table 3.30. The number of least cloudy Landsat images by season and per cent cloud cover

	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
total	37	4	0	0	0	0	0	0	0	0
Jan-Mar	22	6	3	4	2	0	2	0	2	0
Apr-Jun	23	11	4	1	2	0	0	0	0	0
Jul-Sep	15	10	8	4	3	0	1	0	0	0
Oct-Dec	24	10	3	4	0	0	0	0	0	0

Table 3.31. The number of path/rows in the mosaic by number of images per path/row (columns)

	# images	0-1	2-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32-33	34-35	36-37	38-40
total	1113	0	0	0	0	2	0	0	0	0	0	1	3	6	7	9	4	8	1	0	0
Jan-Mar	176	0	7	29	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apr-Jun	279	2	3	4	16	13	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jul-Sep	258	2	1	9	14	14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct-Dec	400	0	0	2	1	10	27	1	0	0	0	0	0	0	0	0	0	0	0	0	0

4 Conclusions

Only Landsat 7 and Landsat 8 were in operations acquiring core data in 2013. Landsat 8 was launched on 11 February 2013 and began acquiring nominal data on 15 April 2013. Landsat 7 acquired operational data for all of 2013. Landsat 8 revisited each location 18 times and Landsat 7 revisited each location 23 times.

Both Landsat 7 and 8 acquire data guided by a long term acquisition plan. Landsat 8 acquired 550 images per day during 2013. The Landsat 8 was specified to acquire 400 images per day. During commissioning it was determined that the sensor could safely meet a higher rate of 550. Studies are underway to establish a safe and prudent long term daily limit to maximize the probability of sustaining the mission until the next generation Landsat satellites are available. In November 2013, Landsat 7 shifted from a global mission to a continental land mass mission to reduce wear and tear on the sensor, while at the same time increasing the daily acquisition from 375 to 434 images/day. This change to the acquisition plan increased Landsat 7 acquisitions during the last quarter of 2013. The objective for both missions is to maximize the daily limit to meet science and resource management needs without jeopardising the longevity of the missions.

Ninety per cent of the images in a best available image mosaic of the 2013 GFOI countries have less than 10% cloud cover. Thirty-two out of 2216 path/rows have best available images with greater than 20% cloud cover. The worst image has 43% cloud cover. Most scenes should be able to be completely sampled with two images, although for the worst cases more images will be needed. Except in a very few path/rows more than 20 images are available from which to sample. In the worst case, Colombia has two path/rows with only 10 or 11 images available. Over 20% of the path/rows in Guyana and Ecuador have cloud cover worse than 20%. Seasonal mosaics would be difficult to produce in most countries.

Landsat 7 and 8 will remain the only optical core missions in operations in 2014. In 2014 Landsat 8 will acquire data for the entire year of Landsat 8 acquisitions and Landsat 7 will acquire using the continental model increasing the number of opportunities significantly. The Landsat 8 long term acquisition plan will continue to evolve within the constraints needed to ensure the long term viability of the mission. Countries with a Jan-Apr dry season will be the primary beneficiaries of full year of Landsat 8 availability in 2014. As a global mission with a long term acquisition plan, the addition of the 2014 GFOI priority countries will not impact the continued coverage of all current GFOI countries. Improvements in the long term acquisition plan suggested through the GFOI country analysis led to an improved global long term acquisition plan for Landsat. About 40000 scenes were acquired in 2013 over the 15 countries involved in GFOI.

5 References

The CEOS Strategy for Space Data Coverage and Continuity in Support of the GEO Global Forest Observations Initiative (GFOI) and Forest Carbon Tracking (FCT) Task, v1.1 (2011). 25th CEOS Plenary, Lucca, Italy, 24 Oct 2011.

CEOS Space Data Coordination Group. (2013). Global Baseline Data Acquisition Strategy (Version 1.0). CEOS SIT-28, Langley, USA, March 13-14, 2013.

CEOS Space Data Coordination Group. (2014a). Global Baseline Data Acquisition Strategy: 2014 Update (Version 2.1). CEOS SIT-29, Toulouse, France, April 8-9, 2014.

CEOS Space Data Coordination Group. (2014b). Space Data Services Strategy for GFOI (Version 1.0). CEOS SIT-29, Toulouse, France, April 8-9, 2014.

Appendix B1 – Search and Access

Landsat data can be searched and downloaded using the four tools listed below.

B1.1 LSIExplorer, EarthExplorer, GloVis and COVE

B1.1.1 EarthExplorer

The USGS EarthExplorer (earthexplorer.usgs.gov) can be used to search and order Landsat data. EarthExplorer provides a Tutorial to guide you through the use of the system. Users must register and login to order data, submit standing requests and to use the bulk download tool.

The date and location are entered using the "Search Criteria" tab. Also in the "Search Criteria" tab is a "Results Options" tab. Increase the "Number of records to return" if you expect your search to return more then 100 records. Under the Data Sets tab set, select the Landsat archive for a general search of the archive or go directly to a GFOI country under the Global Forest Observations Initiative. If the date is not restricted, then a list of all images that meet the spatial criteria will be returned. For example by restricting the date, it's possible to select new images acquired since the last time a national data set was updated. In addition a standing request can be submitted that will result in the user notification whenever a new scene that meets the search criteria is acquired (Figure B1.1).

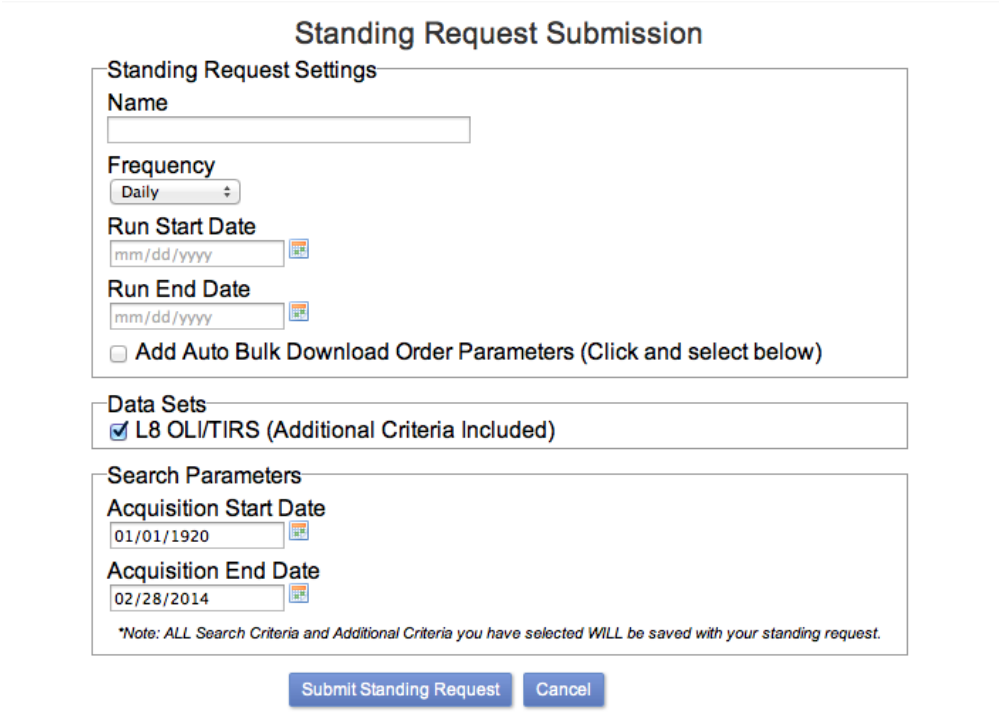


Figure B1.1: EarthExplorer Standing request dialog.

The bulk download tool is integrated in EarthExplorer (earthexplorer/bulk). A filelist interface can also be accessed at earthexplorer.usgs.gov/filelist. The filelist must be a GloVIS scene list, a EarthExplorer Metatdata Export or a list of scene ids. An email will be sent when the scenes are ready for bulk download. A Bulk Download Application (BDA) is needed to download the data (Figure B1.2). Tutorials for acquiring and installing the BDA are provided in EarthExplorer.

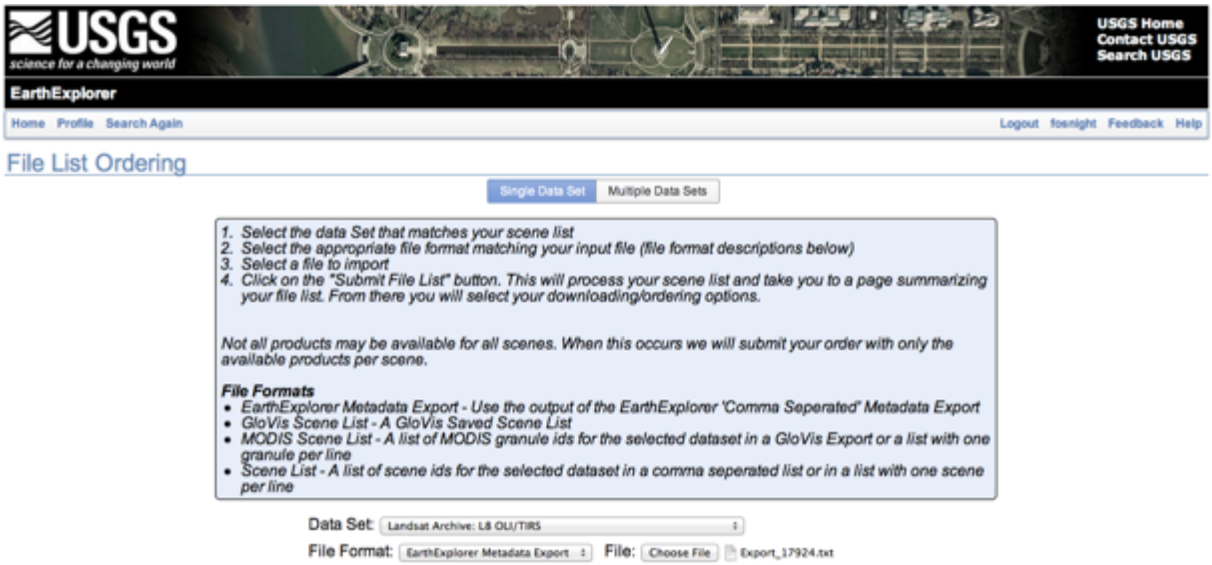


Figure B1.2: Bulk Download Tool dialog

B1.1.2 LSIExplorer

The CEOS Land Surface Imaging (LSI) Explorer (lsiexplorer.cr.usgs.gov) provides a simplified interface into the GFOI countries images in the Landsat Archive. A subscription is associated with each country keeping the lists current. However user notification of new acquisitions is not possible. Access to the Bulk Download Tool is also not possible, since the metadata results cannot be saved to an export file. To download data use EarthExplorer.

B1.1.3 GloVIS

The USGS Global Visualization Viewer (GloVIS – glovis.usgs.gov) can be used to search and order Landsat data. GloVis provides a Quick Start Guide and detailed user guide under its help menu. GloVis is driven by a graphic interface that allows a user to interact and quickly step through the browse data. GloVis is optimized for moderate resolution satellite data available at USGS EROS including Landsat. A scene list can up loaded into GloVis. Scenes can be added and removed from the scene list before ordering. A saved scene list can be used in the bulk download tool.

B1.1.4 COVE

The CEOS COVE tool (http://ceos-cove.org) can be used to search the Landsat and 8 archives. Select the past date range, one of the Landsat missions, and a region, then click on "Add Actual Acquisitions" to view acquired scenes. The browse image and metadata can be viewed and a link to EarthExplorer is available for ordering any single scene (Figure B1.3). Users must be registered in EarthExplorer to order images. Landsat metadata can be downloaded using the Rapid Acquisition Tool. The COVE tool is available in English and Spanish.

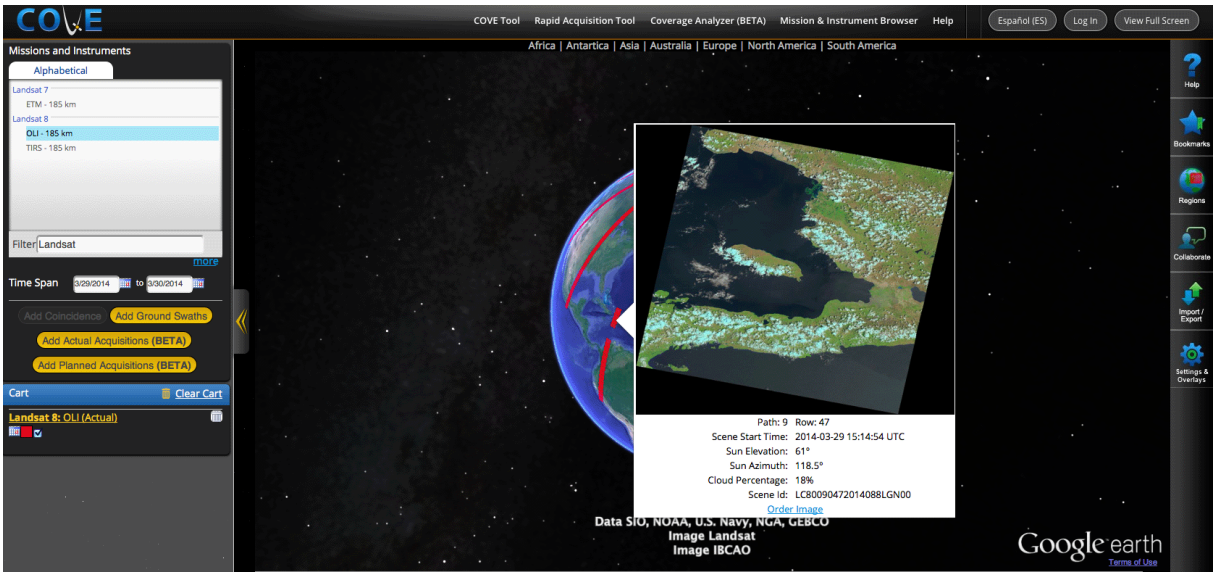


Figure B1.3: Cove dialog and EarthExplorer interface

B1.2 Surface reflectance product

The products delivered on media are calibrated and scaled Top of Atmosphere products. Surface reflectance products can be created using the EROS Science Processing Architecture (ESPA). ESPA is the initial development of a computational framework that integrates Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS), which enables the USGS to process Landsat ETM+ and TM data to retrieve surface reflectance.

Landsat 7 ETM+ data are available as Top-of-Atmosphere (TOA) and provisional surface reflectance products. At this time Landsat 8 OLI/TIRS data are only available as TOA products. The Landsat 8 OLI surface reflectance model will be released in 2014.

Landsat surface reflectance products can be order using Earth Explorer. Information about the surface reflectance products is available at http://landsat.usgs.gov/CDR_LSR.php. Data access is provided through EarthExplorer (http://earthexplorer.usgs.gov) and ESPA (http://espa.cr.usgs.gov/). The contents of the products vary slightly between the two systems. The Landsat Surface reflectance product is delivered as an HDF file by Earth Explorer with the 17 bands listed in Table B1.1.

Table B1.1. The HDF file contains the surface reflectance, temperature, quality assessment (QA) Cloud mask (Fmask) and atmospheric opacity bands.

Band 1 reflectance	Fill QA
Band 2 reflectance	DDV QA
Band 3 reflectance	Cloud QA
Band 4 reflectance	Cloud shadow QA
Band 5 reflectance	Land/Water QA
Band 6 temperature	Adjacent cloud QA
Band 7 reflectance	Atmospheric opacity
Band 8 reflectance	Band 6 fill QA
	Fmask band

The surface reflectance data can also be acquired directly from the ESPA web site (espa.cr.usgs.gov). Additional bands including the Normalized Difference Vegetation Index (NDVI), Normalized Difference Moisture Index (NDMI), Normalized Burn Ratio (NBR), Soil Adjusted Vegetation Index (SAVI), and Enhanced Vegetation (EVI). In ESPA, additional options exist to change the pixel size, crop the image area, and to reproject the data into geographics, Albers Equal Area, Sinusoidal or UTM map projections (Figure B1.4). Please review details about available Landsat Surface Reflectance data products in the On-Demand Product Guide (http://landsat.usgs.gov/documents/cdr_sr_product_guide.pdf). Additional information guides and links can be found under the Surface Reflectance section on http://landsat.usgs.gov/CDR_ECV.php (Figure B1.5).

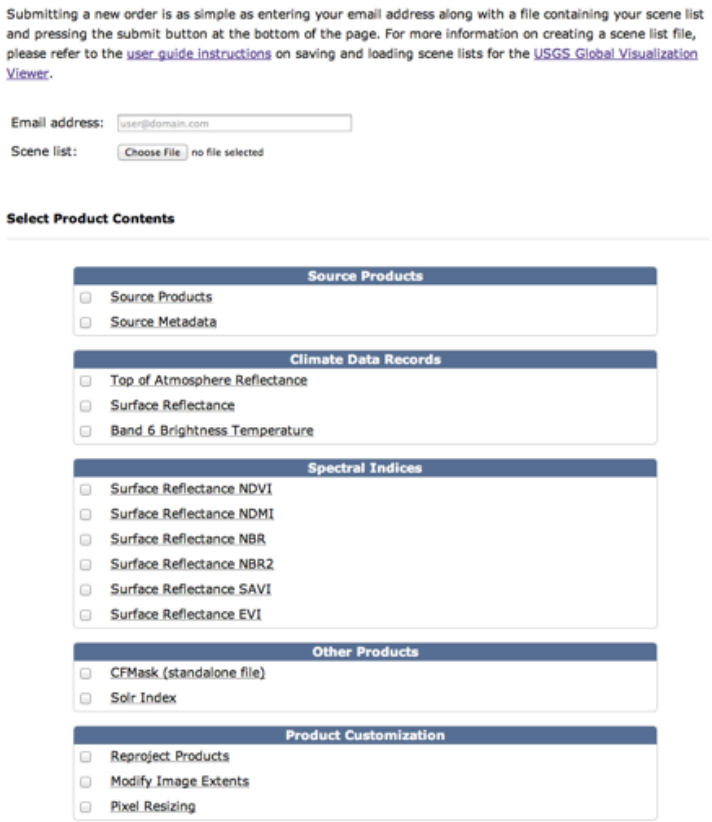


Figure B1.4: Preliminary Landsat Surface Reflectance options

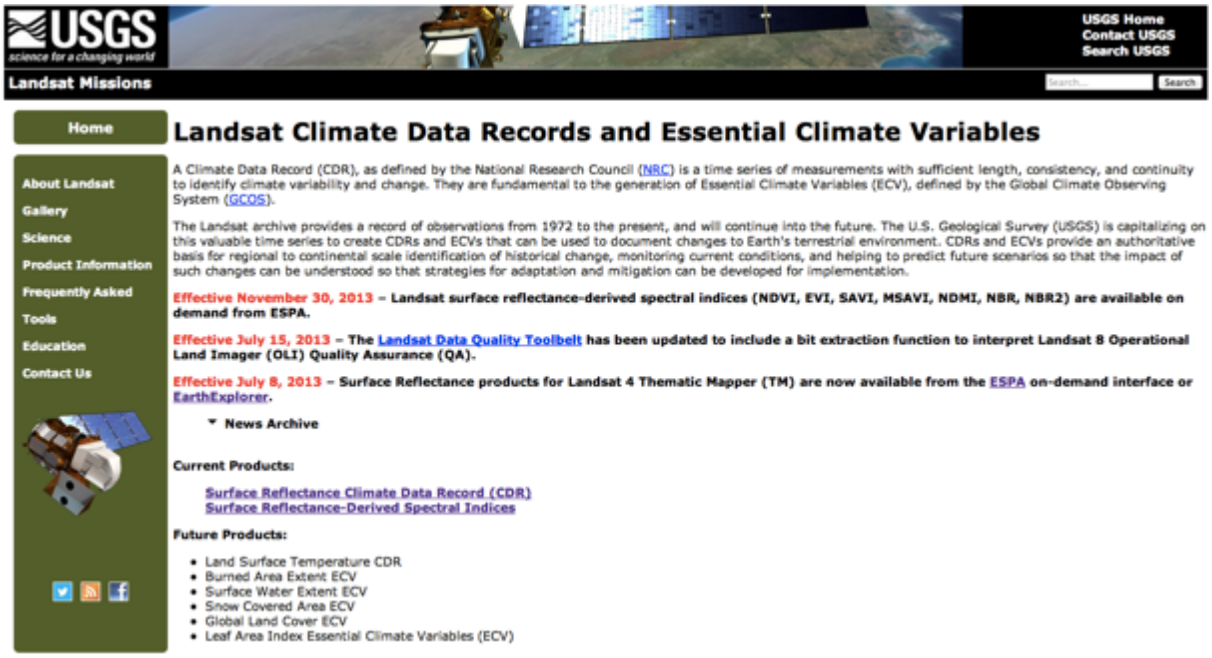


Figure B1.5: Landsat Climate Data Records and Essential Climate Variables

LEDAPS code can be downloaded and used to process data locally. The baselined versions of LEDAPS are hosted by USGS as open source code on a Google Projects site. LEDAPS is a research system and the code is updated frequently. The current version of the code should be used and can be downloaded from the LEDAPS Wiki at http://code.google.com/p/ledaps.

A standing request for data can be created in EarthExplorer to augment existing archives as new data become available. An email will be sent to the user when a new image becomes available that meets the search criteria.

Appendix B2 – Data Delivery

The Landsat products for the 2013 baseline national databases are delivered on hard disks from USGS EROS. The disks containing the 2013 delivery of Landsat data will be held at USGS EROS until requested by the participating country agency either directly or through a GFOI partner, such as SilvaCarbon or FAO. All participating countries will have the complete time series of Landsat 5, 7 and 8 images from 2009 through 2013. The countries included are listed in Table B2.1. Newer data or older data can be acquired online from USGS.

GFOI Countries	delivered	2014 delivery
Algeria		2009-2013, SRTM3, GLS
Argentina		2009-2013, SRTM3, GLS
Australia		No media delivery
Belize		2009-2013, SRTM3, GLS
Bolivia		2009-2013, SRTM3, GLS
Brazil	2009-2012, SRTM2, GLS	No media delivery
Burma		2009-2013, SRTM3, GLS
Cambodia	2009-2012, SRTM2, GLS	2013, SRTM3
Cameroon	2009-2012, SRTM2, GLS	2013, SRTM3
Colombia	2009-2012, SRTM2, GLS	2013, SRTM3
Costa Rica		2009-2013, SRTM3, GLS
DRC	2009-2012, SRTM2, GLS	2013, SRTM3
Ecuador		2009-2013, SRTM3, GLS
Ethiopia		2009-2013, SRTM3, GLS
Guatemala		2009-2013, SRTM3, GLS
Guyana	2009-2012, SRTM2, GLS	2013, SRTM3
Honduras		2009-2013, SRTM3, GLS
Indonesia	2009-2012, SRTM2, GLS	No media delivery
Laos		2009-2013, SRTM3, GLS
Malawi		2009-2013, SRTM3, GLS
Mexico	2009-2012, SRTM2, GLS	2013, SRTM3
Nepal	2009-2012, SRTM2, GLS	2013, SRTM3
Nicaragua		2009-2013, SRTM3, GLS
Pakistan		2009-2013, SRTM3, GLS
Panama		2009-2013, SRTM3, GLS
Peru	2009-2012, SRTM2, GLS	2013, SRTM3
Philipines		2009-2013, SRTM3, GLS
Russia		2009-2013, SRTM3, GLS
Tanzania	2009-2012, SRTM2, GLS	2013, SRTM3
Thailand	2009-2012, SRTM2, GLS	2013 (delivered)
Uganda		2009-2013, SRTM3, GLS
Ukraine		2009-2013, SRTM3, GLS
Vietnam		2009-2013, SRTM3, GLS
Zambia		2009-2013, SRTM3, GLS

Table B2.1 GFOI 2013 countries. https://lta.cr.usgs.gov/ee_help

After the final USGS data delivery on media in early 2014, dissemination of the data to countries will be transition to the Space Data Management System and the Space Data Services. Future plans are documented in the SDCG Space Data Services Paper (Space Data Coordination Group, 2014).


GFOI


CEOS


GEO