Australian Government

Geoscience Australia

Unlocking the Landsat Archive

Work Package 4.1

Pixel Quality Documentation

Author:	Joshua Sixsmith
Contributed By:	
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1.0 Introduction

One of the requirements of the Unlocking the Landsat Archive (ULA) project, is to produce a quality assessment of each Landsat scene. Quality assessments include cloud cover, cloud shadow and saturation. The outcomes from the quality assessments will be used to determine the suitability of a pixel populating the National Nested Grid.
Pixel quality is important to the ULA project as there is a need to identify and assess contaminated pixels. Future workflows and processes may rely on the use of only quality assured pixels.

1.1 Purpose

The purpose of this document is to provide an overview of the Pixel Quality (PQ) process and an insight into the components that make up the PQ workflow. The current components as part of the PQ workflow include:

- Saturation and Null values
- Pixel contiguity (through band/spectral domain)
- Cloud
- Cloud Shadow
- Land/Sea discrimination

1.2 Scope

The scope of this document is to outline the base structure of the pixel quality components and provide some technical detail into the algorithms. Data outputs, dynamic bit setting of each test as well as data extraction are also discussed.

1.3 Audience

The audience for this document are the members of the ULA project and NEO staff.

2.0 Current Modules

As it currently stands, the PQ workflow is only applied to L1T Landsat 5TM and Landsat 7 ETM+ data. L1G data is throughput as several components within the workflow require NBAR data which itself is only applied to L1T data.

2.1 Pixel saturation

The identification of saturated pixels is important for future processing stages such as radiance/reflectance conversions. Over saturated pixels will produce a spectral reflectance that is lower than the actual reflectance.

Input units are in byte-scaled radiance with values ranging from 1-255 with a fill value of 0.

Saturation can be detected by finding the values 1, under saturated, and 255, over saturated.

Saturation tests are applied to every band in the Landsat dataset/scene; except for the panchromatic band in L7 ETM+. This is largely due to the fact that the panchromatic band is of a higher resolution than the other bands. Therefore to have a single quality layer would require that all bands be of the same pixel resolution and geographical extents. While the thermal bands for both the TM and ETM+ sensors are of a lower resolution than bands 1-5 & 7, they have been resampled to the same resolution as bands 1-5 & 7 as part of the LPGS.

The following table (Table 1) indicates the bit values that are set for each saturated pixel in each band. Saturated values will always be zero, whereas non-saturated data will be determined by the bit position.

Table 1 Bit values set for each saturation test

Test	Band	Bit	Value
Saturation	1	0	1
	2	1	2
	3	2	4
	4	3	8
	5	4	16
	61*	5	32
	62*	6	64
	7	7	128

Band 61 and 62 refer to the ETM+ sensor, for the thermal band sampled in both a high gain and low gain state. The TM sensor will correspond to band 61, and the result of saturation in band 6 will be duplicated and set at a bit value of 6 corresponding to band 62 in ETM+.

Process times for detecting saturation takes approximately 9 seconds.

2.2 Band contiguity

Band contiguity is to ensure that valid pixels are consistent through the spectral space within a single scene, thereby allowing the calculation of various indices.

Any pixel from any band containing a null value, set at 0 for Landsat data, will flag the entire spectral space for that pixel as being non-contiguous. Non contiguous pixels will be assigned as zero, whereas contiguous pixels will be set at bit 8 corresponding to a value of 256.

In addition to flagging non-contiguous pixels, interpolated values have been detected in the thermal band of the TM sensor. This has occurred at the eastern and western edges of the scene.

At the scene edges, the pixels are assigned a DN of 1, which are flagged as part of the saturation masking. Lan-Wei has suggested that these are most likely a fill value rather than a pixel too low for the sensor to detect. As a result of the fill value, nearby pixels are an interpolated value, in the range extreme cold (-70^{o} Celsius) to normal (17^{o} Celsius) for the type of landcover.
The data ranges are potentially valid, but we are flagging the pixels located near the edge and including it as part of the contiguity mask. Previously they were picked up in the cloud masks to due their 'cold nature', but are now being removed beforehand. A 3 pixel buffer was used around values with a DN of 1 in order to include the interpolated values. Some valid pixels maybe removed, and some invalid pixels may remain, but this should be fairly minimal.

The following figures (Figure 1 through Figure 4) depict the thermal band anomalies.
The images are of the exact same geographical area, the difference is that the thermal band doesn’t extend as far west as bands 4, 3 and 2.

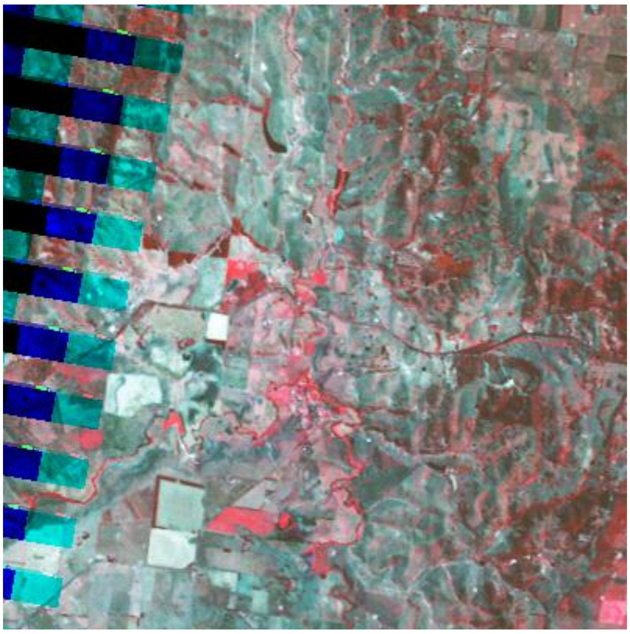

Figure 1 False colour image (4,3,2 RGB)

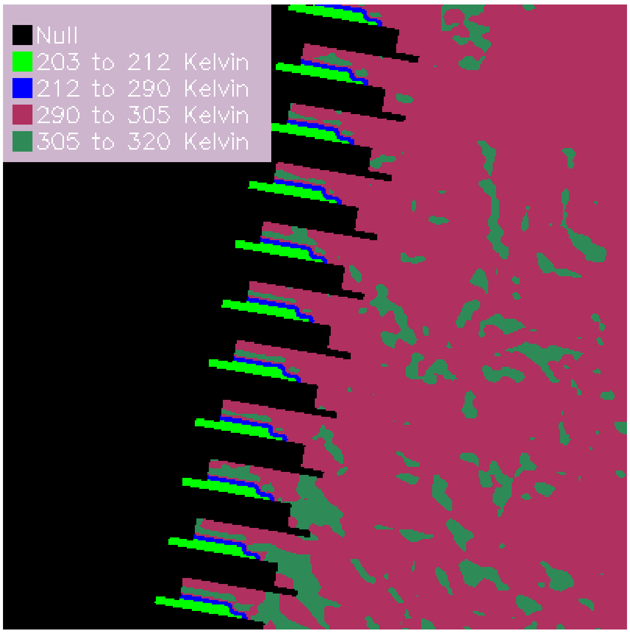

Figure 2 Thermal band classified into different temperature ranges

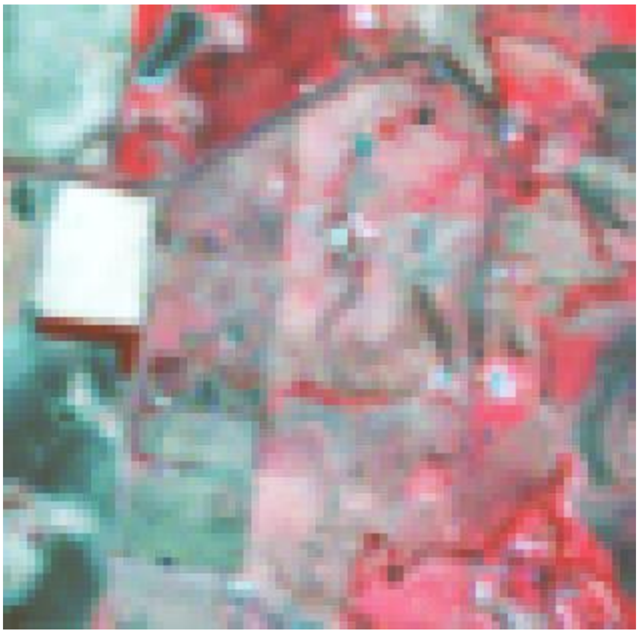

Figure 3 Zoomed portion of Figure 1

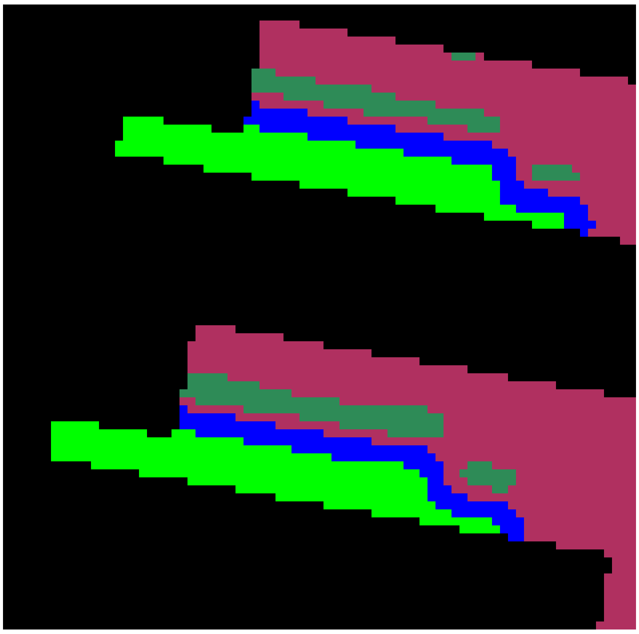

Figure 4 Thermal band classification of Figure 3

The blue colour in Figure 2 and Figure 4 represent the majority of the interpolated values. As one can see, the extreme value 203 Kelvin (approximately -70^{o} Celsius) classified as green doesn't correspond to a frozen landscape that should be seen in Figure 1 or Figure 3.

Another issue has arisen with pixels that may also be due to interpolation and occurs with all bands. The anomaly occurs at the scene edges. However due to band contiguity masking, only bands 1 through 4 on the eastern edge of a scene are affected. What occurs is that when a pixel is not quite over saturated in one band, and not quite under saturated in another band. This is apparent when the images are displayed giving the effect that for the affected pixels, only one band is displayed.

The method used to flag these anomalies, was by employing a 3% contrast enhancement to force pixels to a predictable value, ie become saturated with a value of 255. A 3 pixel buffer of the contiguity mask was used to constrain the flagging of pixels at the scene edge.

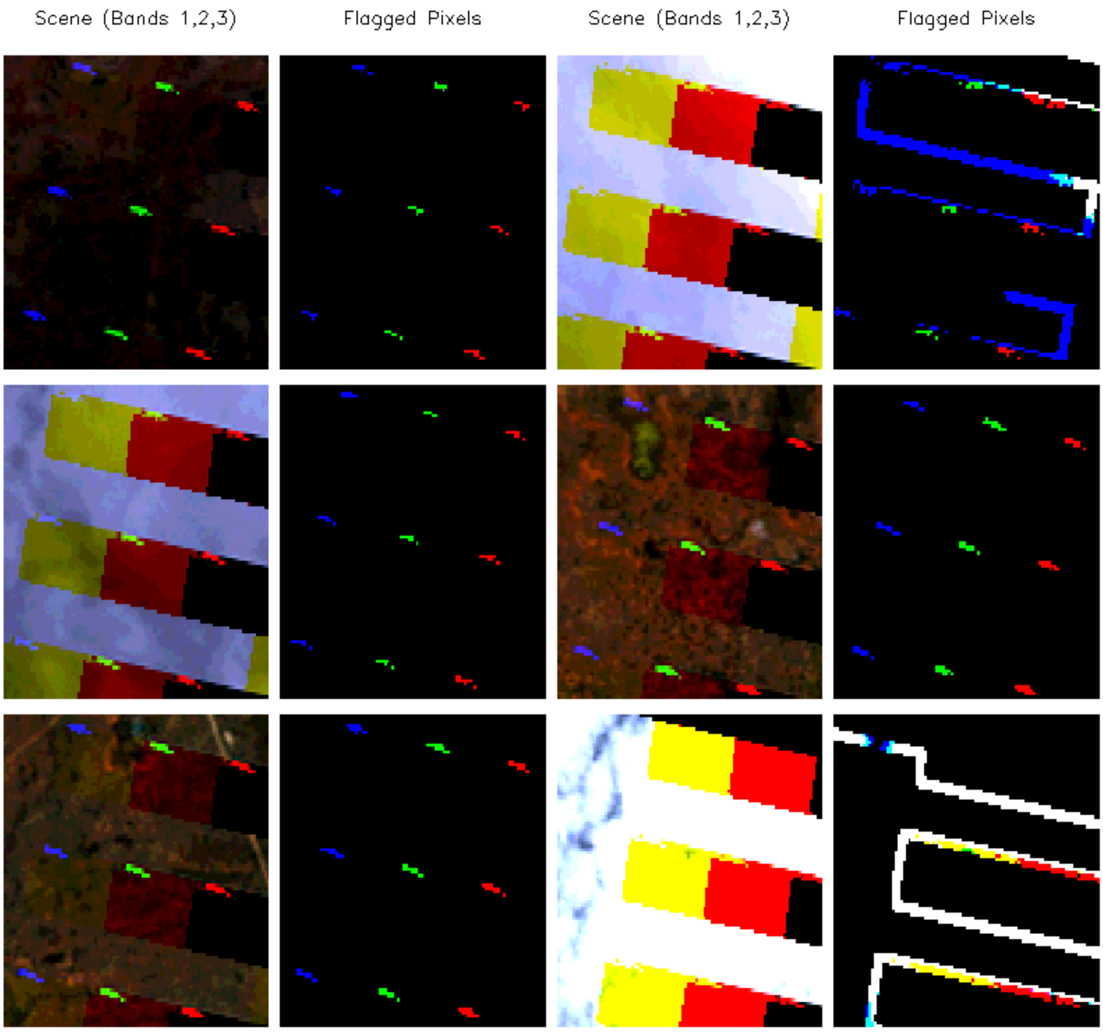

Figure 5 Shows 6 cases of scene edge anomalies and the corresponding flagged pixels

From Figure 5, it is apparent that when there are bright pixels contained within the 3 pixel contiguity buffer such as cloud and soil. Due to the possibility of flagging numerous quality pixels, this method of flagging is not currently implemented. While the total percentage of incorrectly flagged pixels is probably minimal in terms of the entire scene, it would be desirable to find an alternative means or improve the current method.
The anomalies are so far not observable in L7ETM+.

Process times for band contiguity are approximately 4 seconds for L7ETM+ and 15 (on average) secs for L5TM. The longer time for L5TM is due to the extra processing needed for detecting the thermal anomalies described earlier.

2.3 Land/Sea masking

Land/Sea masking is to provide the user with a clipped scene extent of land surface data. This is to ensure that a user dealing with land surface characteristics will only be analysing data with minimal sea interference. Sea pixels are assigned a value of zero, and land pixels are set at a bit value of 9 corresponding to a value of 512.

The ‘TM World Borders’ vector file spliced with a 100K Australian coastal boundary is used as the dataset for land/sea discrimination. The vector file was projected into each of the MGA 94 zones, 48 to 58, with a 100m buffer extending outwards towards the sea. The 100m buffer was applied as a means of keeping more land pixels, as the 100K boundary file doesn’t match the coastline exactly when overlayed with the Landsat scenes.

Initially the vector file was opened for every scene and rasterised in order to create the land/sea mask. However, with the inclusion of the 100K Australian coastal boundary, the number of vertices increased by several million. This led to a 5min processing time just to perform land/sea masking. A solution was to rasterise the entire vector file, one for every zone in the MGA 94 projection. Processing times for land/sea masking now take approximately 1 to 2 seconds.

(The TM World Borders vector file was sourced from http://thematicmapping.org/downloads/world_borders.php)

2.4 Cloud masking

Cloud is considered a contaminant in Remotely Sensed imagery as it interferes with a user’s ability to extract meaningful surface characteristics.

To ensure certainty in cloud detection, a 2 pass approach, similar to what is currently established for WELD. The 2 pass approach will use 2 separate methods of cloud detection. The first method is ACCA developed by Irish (2000 and et al 2006), while the second method if Fmask developed by Zhu and Woodcock (2012).

For both masks, cloud pixels will be set at a value of zero. For non-cloudy pixels, ACCA will be set at a bit value of 10 whereas Fmask will be set at a bit value of 11. This corresponds to values of 1024 and 2048 respectively.

2.4.1 ACCA

Currently the implementation of ACCA uses NBAR as the reflectance data rather than TOAR as used by Irish. The thermal band however is converted to at-satellite temperature in degrees Kelvin, the same as that used by Irish.

The algorithm details are basically the same as described by Irish. One minor addition to the algorithm is the incorporation of a water mask. There were some instances of where water bodies exhibited a relatively high reflectance in the red band, and fell within the temperature threshold range.

The water mask used with ACCA is given by Equation 1 (below).

Equation 1

$$Water = (NDVI < 0.1) \& (b5 < 0.05)$$

The algorithm comprises of two passes; the first is a series of spectral and thermal tests to determine cloudy and ambiguous pixels. The second pass uses thermal tests to determine whether or not the ambiguous pixels are also clouds.

Cloud coverage is reported in the log file as a percent of the entire scene. This includes the non-contiguous/no data areas.

Processing times for ACCA take on average 1 minute.

2.4.2 Fmask

The Fmask algorithm uses TOAR rather than NBAR for reflectance input. The thermal band, like ACCA, is converted to at-satellite temperature in degrees Kelvin.

Fmask (Function of Mask) can create cloud, cloud shadow and snow masks (provided snow is present). For PQ, only the cloud masking part of the algorithm is used. Initial tests comparing the cloud shadow mask derived from Fmask and Geoscience Australia's cloud shadow mask, it was concluded to go ahead with the method developed by Geoscience Australia. The results were more accurate, with cloud shadow shapes being better preserved. Also processing times were much faster. Processing of cloud shadow alone using Fmask took around 4-6mins, while the method developed by Geoscience Australia took on average 1min.

The cloud masking part of Fmask has two passes similar to ACCA. The first pass comprises of a series of spectral tests in order to identify potential cloud pixels. Tests include a whiteness test (clouds generally appear white in colour), a haze optimisation and a water test.
Pass two computes cloud probability layers involving the thermal band and clear sky pixels.

The original code was written in Matlab, and a version was ported into python for use within PQ. There have been no major algorithmic alterations to the code. One addition is the use of the cloud percentage reported by ACCA (the percentage is reported as cloud pixels existing within valid data, rather than the entire scene). Fmask uses a prior probability of 22.5% for a cloudy scene in its final determination of a cloud mask. It was found that for some scenes, a prior probability of 22.5% resulted in a cloud probability threshold that was too high for a large proportion of clouds. Fmask now uses ACCA's estimate of cloud percent as a prior probability statistic. However this statistic is capped to a maximum of 22.5%.

Cloud is reported as a percentage of actual valid data rather than the entire scene.

Processing times for Fmask are approximately 2 minutes.

2.5 Cloud shadow

Like cloud, cloud shadow can also be considered a type image contaminant, as the underlying surface spectral characteristics are not truly represented. Visually and spectrally, dark cloud shadow can exhibit spectral properties similar to that of water, whereas lighter cloud shadow can look spectrally similar to darker vegetation (Luo *et al* 2008).

The cloud shadow algorithm is run twice; once for the cloud detected using ACCA and once for Fmask. The bit positions for non cloud shadow pixels are set at 12 and 13, corresponding to values 4096 and 8192 respectively.

The cloud shadow algorithm is one developed in house at Geoscience Australia and employs a type of region growing. The method uses geometric methods to project cloudy pixels to a location on the surface. A series of spectral tests, using NBAR data, are used to assign weights to pixels which are then used to create a weighted image from which thresholds are derived. The image is then segmented whereby these 'grown regions' are matched with projected cloud pixels which then becomes the cloud shadow mask.

Figure 6 (below) depicts the geometric method used to predict the location of cloud shadow.

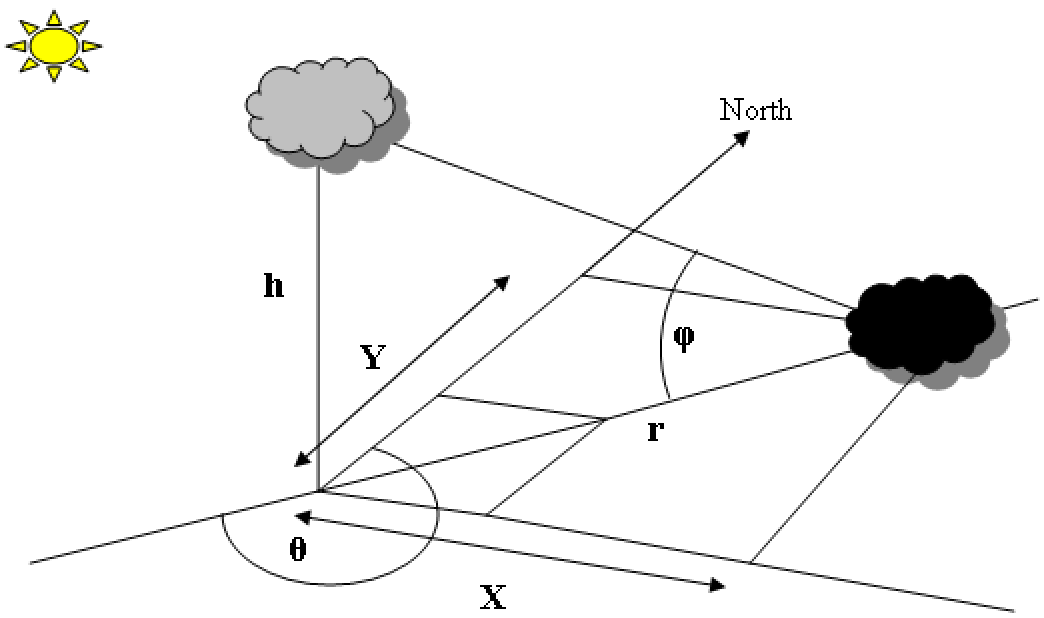

Figure 6 Geometric formulation of cloud shadow

The height of the cloud is determined by environmental lapse rates. Converting the thermal band into degrees Kelvin, the height of a cloud can be estimated using Equation 2 (below).

Equation 2

$$h = \frac{(a-c)}{ELR}$$

Where:

h is cloud height in metres
a is surface air temperature
c is cloud temperature
ELR is the Environmental Lapse Rate

The International Civil Aviation Organization defines a standard as 6.49^{o}C/km. Using a single lapse rate to estimate the cloud height has shown to be very difficult. Currently, the cloud shadow algorithm uses 3 lapse rates to project the cloudy pixels. They are 9.8^{o}C/km for a dry adiabatic lapse rate, 6.4^{o}C/km for a standard or normal lapse rate, and 4.88^{o}C/km for a saturated lapse rate.

The projected cloud distance ‘r’ is given by Equation 3.

Equation 3

$$r = \frac{h}{\tan(\varphi)}$$

Where:

r is the projected cloud shadow distance in metres
h is the cloud base height in metres
φ is the solar elevation angle (assumed constant over the entire image)

The weighted image is derived as follows.
Every pixel starts out with a weight of one. Next a weight of 1 is added to those pixels that have a slope greater than or equal to 0.1 between bands 3 and 4. This is to eliminate some of the darker vegetation as described by Luo *et al* 2008. Next, pixels with a slope greater than or equal to 0.05 between bands 4 and 5 have a weight increase of 1. This is to discriminate between shadows of fallowed land, and unshadowed fallowed land with shadowed vegetation. The final slope is made from band 4 through 7. Pixels that are slightly greater than the horizontal (0.01) have their weights added by one. This last slope is used to eliminate more of the fallowed land as well as soils and dry grasses. Additional slopes could be used to aid in discriminating other spectrally similar features, and whether to increase or decrease weights. But at this stage we have settled with 3. Additional testing on processed images will no doubt find cases where other weighting systems will need to be defined for differing land covers.

The final weighting is assigned to water pixels, and set quite high with a value of 9. This is because deep water and less turbid water, is generally low in all bands. So when computing a weighted summation, unless water is scaled high using a high weighting, it will generally still be within valid thresholds.

The water mask used within the cloud shadow procedure is the same as that used within ACCA, given in Equation 1.

The equation for the weighted sum is given in Equation 4 (below). Note that bands 5 and 7 the weights are doubled in order to further differentiate shadowed vegetation and fallowed land.

Equation 4

$$W\_sum = weights \times (b1 + b2 + b3 + b4) + 2 \times weights \times (b5 + b7)$$

Processing times for detecting cloud shadow range from 35 seconds to 1 minute 30 seconds.

2.6 Topographic shadow

Topographic shadow is similar to cloud shadow, but rather than the cloud obfuscating the terrain, it is the terrain that is casting shadows onto itself.

A method for deriving topographic shadow has been developed here at Geoscience Australia. The original code was developed in FORTRAN, and a version has now been ported to python. A version of the python code suitable for productive purposes has been tested successfully using a global 3 sec DEM. The DEM used is the same as that used by the LPGS to create the L1T/L1G products.

Topographic shadow is set to zero, while non-topographically shaded areas are set to bit 14 corresponding to a value of 16384.

The algorithm is comprised of two parts. The first is to detect cast shadow, while the second part is used to detect self shadow.

Processing times for topographic shadow are approximately 5 minutes.

Topographic shadow is currently not included in the PQ work flow.

3.0 Data outputs

3.1 Data formats

The production format of the pixel quality assessment is currently GeoTIFF stored as an unsigned 16-bit integer. This format may be reworked in the future to NetCDF4.

3.2 Co-ordinates

The output co-ordinate system will be the same as the input, with a pixel size of 25m. See TRIM document D2011-182055 for specifics.
Due to the categorical nature of the PQ file, applying a geo-transformation to the file could result in a change in the numerical value which represents a specific quality code. If a user desires a co-ordinate system to the original, it is best to mask the required dataset with the relevant PQ prior to geometric transformation.

3.3 Data structure

The product output will consist of a 16-bit binary code structure. The final bit (bit 15) is currently not set as no test has been developed. Table 2 (below) presents the current tests and their corresponding numeric bit.

Table 2 PQ tests and corresponding set bit

Test	Bit	Value	Cumulative Sum
Saturation band 1	0	1	1
Saturation band 2	1	2	3
Saturation band 3	2	4	7
Saturation band 4	3	8	15
Saturation band 5	4	16	31
Saturation band 61*	5	32	63
Saturation band 62*	6	64	127
Saturation band 7	7	128	255
Contiguity	8	256	511
Land/Sea	9	512	1023
ACCA	10	1024	2047
Fmask	11	2048	4095
Cloud Shadow (ACCA)	12	4096	8191
Cloud Shadow (Fmask)	13	8192	16383
Topographic Shadow	14	16384	32767
#	15	32786	65535

The final product can be interpreted as a sequence of binary values. For example, the number 13166 is the binary value 0011001101101110. Reading from right to left gives the following readout:

Band 1: Saturated
Band 2: Clear
Band 3: Clear
Band 4: Clear
Band 5: Saturated
Band 61: Clear
Band 62: Clear* (As this is from a Landsat 5TM scene, the flagged locations are duplicated from band 6)
Band 7: Saturated
Contiguity: Clear
Land/Sea: Land
ACCA: Cloud
Fmask: Cloud
Cloud Shadow (ACCA): Clear
Cloud Shadow (Fmask): Clear
Topographic Shadow: Not set
(Spare bit): Not set

One can also extract the individual pixel quality tests and create a mask for each. Within python, the PQ array can be queried using the '& 'operator. For example to extract the band contiguity mask, query the PQ array as follows:

Contiguity = (PQ & 256)

Another method revolves around only taking quality pixels. Currently, 13 is the largest bit that is set, which corresponds to a value of 8192. If a pixel was to pass every test then the cumulative sum of each test equates to 16383 as given in Table 2 (above). Therefore one can simply create a mask for pixels matching the value 16383.

One can also combine datasets in order to create a certainty measure. Using the two cloud tests as an example, a certainty measure can be constructed using the bit values. Table 3 (below) outlines an example certainty measure for a pixel being cloudy.

Table 3 Cloud certainty measure

	Cloudy	Probably Cloudy	Probably Cloudy	Clear
ACCA	0	0	1	1
Fmask	0	1	0	1

0011001111111111: Cloudy (Both ACCA and Fmask detect cloud)
0011101111111111: Probably Cloudy (ACCA but not Fmask detects cloud)
0011011111111111: Probably Cloudy (Fmask but not ACCA detects cloud)
0011111111111111: Not cloudy (Completely clear in this instance. No tests failed.)

3.4 Naming convention and file structure

As of November 2012, a naming convention and file structure has yet to be finalised. Currently the file structure is similar to that of L1 and NBAR products.

LS5_TM_PQ_P55_GAPQ01-002_093_084_20060130
- Readme.txt
- **Scene01**
  - L5093084_08420060130_1111111111111100.tif
  - ACCA_LOGFILE.txt
  - FMASK_LOGFILE.txt
  - ACCA_CLOUD_SHADOW_LOGFILE.txt
  - FMASK_CLOUD_SHADOW_LOGFILE.txt

The ‘Readme.txt’, if included, will contain information regarding the interpretation of the numbers representing the pixel quality, as well methods for extracting pixel quality layers.

The PQ filename will include a series of 1 and/or zeros indicating which tests have been run. In the above example, the two zeros at the end represent topographic shadow and the unset bit for which no test currently exists.

4.0 Future Development

As the PQ workflow is comprised of several individual algorithms, each algorithm, for example ACCA, can be updated with a version that detects cloud more accurately than the previous version. It can even be completely replaced with another more accurate method.

Updating the land/sea mask with a vector file that better represents the coastline, Australia and/or external country coastlines will improve land/sea discrimination.

The advantage of having specific bits being set for each PQ test is that a user only needs to rerun the relevant PQ test that has been updated and reset the corresponding bit to the PQ file. If tests are related, for instance cloud and cloud shadow, then both tests will need to be rerun.

Current products produced from NBAR and masked by the PQ process, are by default masked using the results from every PQ test. Depending on the project, a user can pick and choose which quality masks in order to customise a quality layer. This procedure is briefly outlined in 3.3.

There is also a spare bit not set within the 16-bit PQ image file. Another test can be developed, run and output to the existing PQ file without needing to rerun the entire PQ workflow. If there are more PQ tests required, then the file data type will need to be updated to a 32-bit (or higher if the case may be) file.

5.0 Glossary

Item	Description
NBAR	Nadir BRDF (Bi-directional Reflectance Distribution Function) Adjusted Reflectance
TOAR	Top Of Atomosphere Reflectance
DEM	Digital Elevation Model
LS5 TM	Landsat 5 Thematic Mapper
LS7 ETM+	Landsat 7 Enhanced Thematic Mapper Plus
ACCA	Automated Cloud Cover Assessment
RGB	Red Green Blue
NDVI	Normalised Difference Vegetation Index
MGA	Map Grid of Australia
UTM	Universal Transverse Mercator
NEO	National Earth Observation
NetCDF	Network Common Data Form
L1T	Level 1 Terrain Corrected
L1G	Level 1 Systematic Corrected
GeoTIFF	Georeferenced Tagged Image File Format
Fmask	Function of Mask
b1, b2	band 1, band 2 etc

6.0 References

Irish, R., 2000, Landsat 7 Automatic Cloud Cover Assement, sourced: http://landsathandbook.gsfc.nasa.gov/pdfs/ACCA_SPIE_paper.pdf, last accessed 12/11/2012

Irish, R.R., Barker, J.L., Goward, S.N., Arvidson, T., 2006, Characterization of the Landsat-7 ETM+ Automated Cloud –Cover Assessment (ACCA) Algorithm, *Photogrammetric Engineering & Remote Sensing*, Vol. 72, No. 10, pp. 1179-1188.

Luo, Yi., Trishchenko, A.P., Khlopemkov, K.V., 2008, Developing clear-sky, cloud and cloud shadow mask for producing clear-sky composites at 250-meter spatial resolution for the seven MODIS land bands over Canada and North America, *Remote Sensing of Environment*, Vol 112, Issue 12, pp. 4167-4185.

Zhu, Z. and Woodcock, C. E., Object-based cloud and cloud shadow detection in Landsat imagery, Remote Sensing of Environment (2012), doi:10.1016/j.rse.2011.10.028

7.0 Appendix A

LS7_ETM_OTH_P51_GALPGS01-002_092_086_20050112
LS5_TM_OTH_P51_GALPGS01-002_092_086_20050120
LS7_ETM_OTH_P51_GALPGS01-002_106_072_20060102
LS7_ETM_OTH_P51_GALPGS01-002_092_086_20060115
LS5_TM_OTH_P51_GALPGS01-002_092_086_20060123
LS7_ETM_OTH_P51_GALPGS01-002_092_086_20070102
LS5_TM_OTH_P51_GALPGS01-002_092_086_20070126
LS5_TM_OTH_P51_GALPGS01-002_092_080_20070721
LS7_ETM_OTH_P51_GALPGS01-002_092_085_20080105
LS5_TM_OTH_P51_GALPGS01-002_092_086_20080113
LS7_ETM_OTH_P51_GALPGS01-002_092_086_20080121
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LS7_ETM_OTH_P51_GALPGS01-002_095_083_20100116
LS7_ETM_OTH_P51_GALPGS01-002_091_077_20100119
LS7_ETM_OTH_P51_GALPGS01-002_100_078_20100119
LS7_ETM_OTH_P51_GALPGS01-002_095_082_20100116
LS5_TM_OTH_P51_GALPGS01-002_095_082_20100124
LS5_TM_OTH_P51_GALPGS01-002_095_083_20100124
LS7_ETM_OTH_P51_GALPGS01-002_092_083_20100126
LS7_ETM_OTH_P51_GALPGS01-002_092_086_20100126
LS7_ETM_OTH_P51_GALPGS01-002_115_066_20100128
LS7_ETM_OTH_P51_GALPGS01-002_115_075_20100128
LS7_ETM_OTH_P51_GALPGS01-002_115_076_20100128
LS7_ETM_OTH_P51_GALPGS01-002_115_077_20100128
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LS7_ETM_OTH_P51_GALPGS01-002_115_079_20100128
LS7_ETM_OTH_P51_GALPGS01-002_095_082_20100201
LS7_ETM_OTH_P51_GALPGS01-002_095_083_20100201
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LS5_TM_OTH_P51_GALPGS01-002_095_083_20100209
LS5_TM_OTH_P51_GALPGS01-002_102_075_20100210
LS5_TM_OTH_P51_GALPGS01-002_109_066_20100211
LS5_TM_OTH_P51_GALPGS01-002_091_081_20100212
LS5_TM_OTH_P51_GALPGS01-002_105_078_20100215
LS7_ETM_OTH_P51_GALPGS01-002_104_069_20100216
LS5_TM_OTH_P51_GALPGS01-002_106_078_20100222
LS7_ETM_SYS_P31_GALPGS01-002_095_082_20100305
LS7_ETM_SYS_P31_GALPGS01-002_095_083_20100305
LS7_ETM_OTH_P51_GALPGS01-002_095_082_20100321
LS7_ETM_OTH_P51_GALPGS01-002_095_083_20100321
LS5_TM_SYS_P31_GALPGS01-002_095_082_20100329
LS5_TM_OTH_P51_GALPGS01-002_095_083_20100329
LS7_ETM_OTH_P51_GALPGS01-002_095_082_20100406
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LS7_ETM_OTH_P51_GALPGS01-002_095_083_20100609
LS7_ETM_OTH_P51_GALPGS01-002_095_082_20100625
LS7_ETM_OTH_P51_GALPGS01-002_095_083_20100625
LS7_ETM_OTH_P51_GALPGS01-002_095_082_20100711
LS7_ETM_OTH_P51_GALPGS01-002_095_083_20100711
LS7_ETM_OTH_P51_GALPGS01-002_095_082_20100727
LS7_ETM_OTH_P51_GALPGS01-002_095_083_20100727
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LS7_ETM_SYS_P31_GALPGS01-002_095_083_20100812
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LS5_TM_OTH_P51_GALPGS01-002_095_083_20100905
LS7_ETM_SYS_P31_GALPGS01-002_095_082_20100913
LS7_ETM_SYS_P31_GALPGS01-002_095_083_20100913
LS5_TM_OTH_P51_GALPGS01-002_095_082_20101007
LS5_TM_OTH_P51_GALPGS01-002_095_083_20101007
LS7_ETM_SYS_P31_GALPGS01-002_095_082_20101015
LS7_ETM_SYS_P31_GALPGS01-002_095_083_20101015
LS5_TM_SYS_P31_GALPGS01-002_095_083_20101023
LS7_ETM_SYS_P31_GALPGS01-002_095_082_20101031
LS7_ETM_SYS_P31_GALPGS01-002_095_083_20101031
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LS5_TM_OTH_P51_GALPGS01-002_095_082_20101210
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LS5_TM_OTH_P51_GALPGS01-002_095_082_20101226
LS5_TM_OTH_P51_GALPGS01-002_095_083_20101226