### Cloud Cover Assessment CCA – Artificial Thermal (AT)-ACCA

#### Background/Introduction

Cloud cover assessment for L8/9 will be performed via a series of intermediate CCA algorithms, whose outputs will be resolved into a final mask. The Expanded AT-ACCA (Artificial Thermal Automated Cloud Cover Assessment) algorithm is one such intermediate process. It is a two-phase algorithm: The first phase is a decision tree based on the L7 ACCA algorithm, with the thermal band replaced by a combination of reflective bands. The second phase is a voting schema to resolve ambiguous pixels. The output of these two algorithms are combined into an intermediate CCA mask.

#### Inputs

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Descriptions**  | **Units** | **Level**  | **Source** | **Type** |
| OLI Scene data (L1G), as TOA reflectance | none (reflectance) | Scene, OLI Bands 2-7. |  | float |
| Solar elevation angle | degrees | Scene | Metadata | float |

#### Outputs

The output of each CCA component is an intermediate cloud mask file – a 16 bit image of the same dimensions as the L1Gs scene. The standardized format of the cloud mask file is:

|  |  |  |
| --- | --- | --- |
| Bit | Flag description | Values |
| 0 | Designated Fill | 0 for image data1 for fill data |
| 1 | Unused |  |
| 2 | Unused |  |
| 3 | Unused |  |
| 4-5 | Water confidence | 00 = Not set01 = Low confidence10 = Mid confidence11 = High confidence |
| 6-7 | Unused |  |
| 8-9 | Unused |  |
| 10-11 | Snow/Ice confidence | same as water confidence |
| 12-13 | Unused |  |
| 14-15 | Cloud confidence | same as water confidence |

Table 6‑49. Cloud mask file bit format, as used by AT-ACCA

A byte value of 1 (00 01 hex) is reserved for fill data. It should not be possible to reach this value when processing a non-fill pixel.

#### Procedure

The main loop of the CCA process opens the band files and output files, and reads information from the metadata. It then – for each non-fill pixel – passes the band reflectance values to the evaluation function for each CCA algorithm. The return value from the algorithm is written to the intermediate CCA mask file. The detailed procedure for the CCA main loop can be found in the CCA Control System ADD.

The Expanded AT-ACCA evaluation function is a two-phase algorithm based on the L7 ACCA algorithm.

The first phase of the AT-ACCA algorithm follows the structure of phase 1 of the Landsat 7 ACCA algorithm. Because the ACCA algorithm uses the L7 thermal band, in AT-ACCA an artificial thermal (AT) band is created from the OLI reflective bands. The AT band is then used with the other OLI bands to classify the scene pixels and assign a confidence score to them. This phase may classify a pixel as Water or Snow/Ice; flags for those classes are reserved in the cloud mask file structure. The AT-ACCA algorithm is also capable of Vegetation classification, but because the accuracy is poor it is not planned to use this algorithm for that purpose.

The second phase of Expanded AT-ACCA is known as the 'gD02' algorithm. It is a voting algorithm, intended to resolve some of the pixels designated as ambiguous by the earlier phases. The gD02 algorithm is a series of threshold tests using the reflective bands and the AT band. Each successful test carries one vote. 2 or more votes indicates that a pixel is clear, 0 votes indicates that it is cloudy, while 1 vote allows the ambiguous designation to stand.

The detailed procedure for the Expanded AT-ACCA evaluation function is:

1. Calculate the AT (Artificial Thermal) band.

The AT band is calculated from the Landsat-like reflectance bands.

AT = -92.7\*ND(B4,B6) + 261.4\*ND(B3,B7) - 48.8\*ND(B3,B6) - 17.5\*ND(B5,B3) - 146.9\*ND(B2,B7) + 58.7\*ND(B4,B2) - 117\*ND(B3,B2) + 172\*CSA\*B6 + 76\*CSA\*B5 + 151\*CSA\*B4 - 951\*CSA\*B3 + 539\*CSA\*B2 + 28\*B7 - 132\*B6 - 106.2\*B5 - 22.4\*B4 + 633.1\*B3 - 443.6\*B2 + 302.0986

where ND(x,y) = The normalized difference between x and y.

 = (x – y)/(x + y)

 CSA = The cosine of the solar zenith angle.

 (Note that the metadata may only provide the solar elevation angle. Zenith = 90 degrees – Elevation.)

 Bx = The reflectance in OLI band x.

 AT = The calculated AT band value.

The equation used to calculate the AT band was arrived at by an empirical fit to a test set of over 1 million pixels of L7 data. It has no scientific derivation.

Prototype code for the AT band calculation is provided in the cubist\_therm.c routine.

1. Phase 1: Perform the AT-ACCA cloud detection algorithm.
	1. B4 test #1: If B4 > 0.08, go to 2.a.i.
		1. NDSI test #1: If ND(B3,B6) > -0.25 and < 0.7, go to step 2.a.i.1. (ND(B3,B6) is known as NDSI, the Normalized Differential Snow Index.)
			1. AT test: If AT < 300, go to 2.a.i.1.a.
				1. B6composite test: If (1-B6)\*AT < 225, go to step 2.a.i.1.a.i.

B54 ratio test: If B5/B4 < 2.25, go to step 2.a.i.1.a.i.1.

B53 ratio test: If B5/B3 < 2.2, go to step 2.a.i.1.a.i.1.a.

B56 ratio test: If B5/B6 > 1, then this pixel is a cloud. Set the output value to high confidence cloud. (CCA\_INT\_CLOUD\_HIGH)

If any of the B56, B53, or B54 ratio tests fail, the pixel is temporarily designated as ambiguous, and proceed to Phase 2.

* + - * 1. If the B6composite test fails, perform the B6 test: If B6 < 0.08, then this pixel is clear. Set the output value to clear of unknown class. (Low value for cloud confidence and low value for class confidence. This is set by the value CCA\_INT\_UNKNOWN\_LOW + CCA\_INT\_CLOUD\_LOW.)
				2. If the B6 test fails, temporarily designate the output value as ambiguous, and proceed to Phase 2.
			1. If the AT test fails, this pixel is clear. Set the output value to clear. (CCA\_INT\_UNKNOWN\_LOW + CCA\_INT\_CLOUD\_LOW)
		1. If the NDSI test #1 fails, perform NDSI test #2: If ND(B3,B6) > 0.8, then the pixel is snow or ice. Set the output value to high confidence snow. (CCA\_INT\_SNOW\_HI + CCA\_INT\_CLOUD\_LOW)
		2. If NDSI test #2 fails, the pixel is not snow but is not a cloud. Set the output value to clear. (CCA\_INT\_UNKNOWN\_LOW + CCA\_INT\_CLOUD\_LOW)
	1. If B4 test #1 fails, perform B4 test #2: If B4 < 0.07, then the pixel is water. Set the output value to mid confidence water. (CCA\_INT\_WATER\_MID + CCA\_INT\_CLOUD\_LOW) The confidence is set to mid instead of high because the ACCA algorithm does not do a good job at water discrimination, so this test is not very effective.
	2. If B4 test #2 fails, the pixel is not water but is not a cloud. Temporarily designate the output value as ambiguous, and proceed to Phase 2.
1. If the output from Phase 1 is non-ambiguous, skip Phase 2.
2. Phase 2: gD02 tests. The gD02 tests are a series of threshold tests arrived at by statistical analysis of L7 data. They have no scientific derivation. They are only run when the output of the AT-ACCA algorithm (Phase 2) is ambiguous.
	1. Before running the gD02 tests, A 'g score' is initialized to zero. Every successful test increments the g score by 1.
	2. The gD02 tests can be run in any sequence. All of them must be performed. The tests are as follows:

|  |  |
| --- | --- |
|  | **Test is successful if parameter** |
| **Test Parameter** | **is less than** | **or is greater than** |
| B2 | 0.140 | *n/a* |
| B3 | 0.111 | *n/a* |
| B4 | 0.093 | *n/a* |
| B6/nfac | 0.087 | 0.481 |
| B4/B2 | 0.640 | 1.034 |
| ND(CSA\*B2,B5) | -0.454 | 0.262 |
| ND(B2,B6) | -0.138 | 0.716 |
| CSA\*B2/B7 | 0.736 | 3.914 |
| B4/B3 | 0.810 | 1.075 |
| ND(B3,B5) | -0.404 | 0.160 |
| ND(B3,B6) | -0.186 | 0.716 |
| ND(B3,B7) | -0.018 | 0.754 |
| ND(CSA\*B4,B5) | -0.566 | -0.016 |
| ND(B4,B6) | -0.232 | 0.692 |
| ND(B4,B7) | -0.030 | 0.738 |
| ND(B6,B7) | -0.050 | 0.300 |

where nfac = The normalization factor for OLI bands 2 through 7. This is the square root of the sum of the square of the band reflectances.

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* 1. When all tests have been performed, the g score is examined. If it is equal to 0 (none of the tests were successful) then the pixel is a high confidence cloud (CCA\_INT\_CLOUD\_HIGH). If the g score is 2 or larger (2 or more of the tests were successful), the pixel is clear (CCA\_INT\_UNKNOWN\_LOW + CCA\_INT\_CLOUD\_LOW). For all other outcomes (g=1), the pixel remains ambiguous.
	2. If the pixel is still considered to be ambiguous, it is set to mid confidence cloud. (CCA\_INT\_CLOUD\_MID)
1. Return the output value.