A Comparison of Landsat TM and ETM+ Cloud Detection Algorithms

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Introduction

Following the release of the Landsat Archive, there has been an increased interest in automatically processing large volumes of imagery. Radiometric and topographic preprocessing methods have already been improved, and the next challenge is cloud masking. A number of automated cloud detection algorithms have been developed in response to this need, and our goal was to compare a selection of cloud masks to gain preliminary insight into their relative strengths.

Methods

We evaluated six cloud detection algorithms' agreements for cloud-free, cloud, and shadow areas in one Landsat 5 TM image from WRS path 41 row 33 from August 3, 1999. This comparison was performed with default settings for the following algorithms:

Fmask - LEDAPS[1]
Fmask treats cloud and shadow layers as 3D objects determined via segmentation, where solar illumination and sensor view angles are used to predict possible cloud shadow locations. This version of Fmask 1.6.3 processes the NASA Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) surface reflectance product.

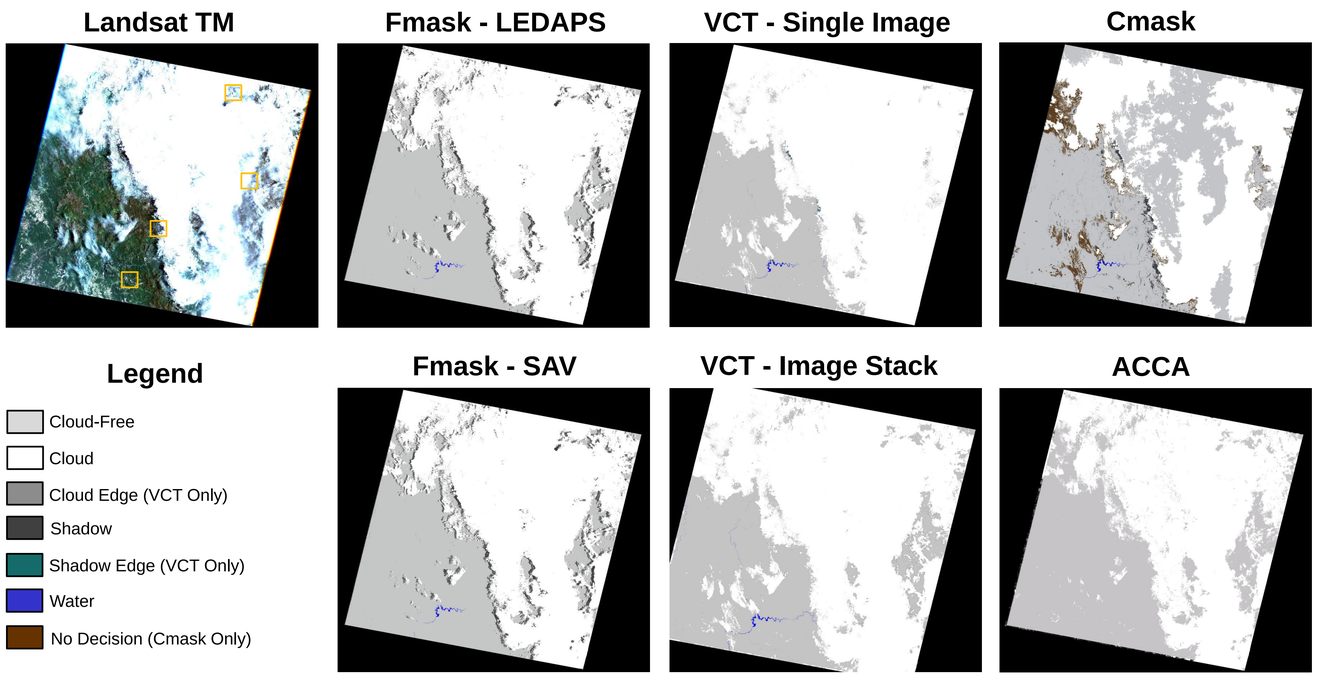
Fmask - Standalone Version (SAV)
This version of Fmask 1.6.3 processes unmodified DN imagery from the Landsat Archive.

VCT - Single Image[2]
VCT calculates cloud heights using temperature and a normal lapse rate. Shadow locations are predicted according to solar illumination geometry and dark pixel detection. This version of VCT processes a single Landsat image, a DEM, and a landcover map.

VCT - Image Stack[3]
This version of VCT processes a dense stack of Landsat images, a DEM, and a landcover map. This version of VCT generates cloud masks for each input Landsat image; these masks are informed by other Landsat images in the stack.

Cmask
Cmask implements the Fmask algorithm in the C programming language but does not apply the segmentation-based cloud shadow detection approach. Instead, it uses IR band thresholds for dark areas around proposed cloud shadow locations.

ACCA
ACCA is a cloud classifier designed to estimate scene-level cloud cover. Unlike the other cloud detection algorithms in this comparison, ACCA was not designed to produce a per-pixel cloud mask for each pixel in a Landsat scene.



Results

Cloud-Free Agreement

	Fmask - LEDAPS	Fmask - SAV	VCT - Single Image	VCT - Image Stack	Cmask
Fmask - SAV	91.2%				
VCT - Single Image	75.9%	73.2%			
VCT - Image Stack	80.8%	78.6%	85.2%		
Cmask	52.6%	51.8%	50.5%	51.5%	
ACCA	82.5%	85.1%	66.1%	74.0%	50.4%

Cloud Agreement

	Fmask – LEDAPS	Fmask - SAV	VCT - Single Image	VCT - Image Stack	Cmask
Fmask - SAV	97.1%				
VCT - Single Image	85.1%	82.9%			
VCT - Image Stack	89.3%	87.1%	93.6%		
Cmask	38.4%	60.9%	64.3%	60.2%	
ACCA	93.3%	94.8%	80.3%	84.2%	59.7%

Shadow Agreement

	Fmask - LEDAPS	Fmask - SAV	VCT - Single Image	VCT - Image Stack
Fmask - SAV	42.5%			
VCT - Single Image	1.4%	1.3%		
VCT - Image Stack	0.0%	0.0%	0.0%	
Cmask	9.1%	8.4%	6.1%	0.0%

Discussion

This comparison of Landsat TM and ETM + cloud-detection algorithms demonstrates a range of agreement levels for cloud-free, cloud, and shadow areas of the test image. The most mathematically similar algorithms (i.e., Fmask - LEDAPS/Fmask – SAV and VCT - Single Image/VCT - Image Stack) tend to show the highest levels of agreement. Generally, cloud agreement values were higher than shadow agreement values.

This comparison is not exhaustive, as some of the algorithms include adjustable cloud and shadow detection parameters and buffering distances. A more comprehensive understanding of the relative strengths of these algorithms is necessary to help scientists make more informed decisions with respect to which cloud detection algorithm and parameters are most appropriate for a particular remote sensing application.

Footnotes

[1] MATLAB code and documentation for both versions of Fmask are available at http://code.google.com/p/fmask
[2] VCT requires a dense stack of Landsat imagery in order to function as intended. However, this instance of VCT was run with only one input Landsat image.
[3] VCT requires that the dense stack of input imagery have the same common area. Comparisons between this version of VCT and the other algorithms are performed on the common area for all images in the stack.

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