Using Information From Prior Satellite Scans to Improve Cloud Detection Near the Day-Night Terminator

Christopher R. Yost[1], Patrick Minnis[2], Qing Trepte[1], Rabindra Palikonda[1], J. Kirk Ayers[1], and Douglas A. Spangenberg[1]

[1]Science Systems & Applications, Inc., Hampton, VA [2]NASA Langley Research Center, Hampton, VA

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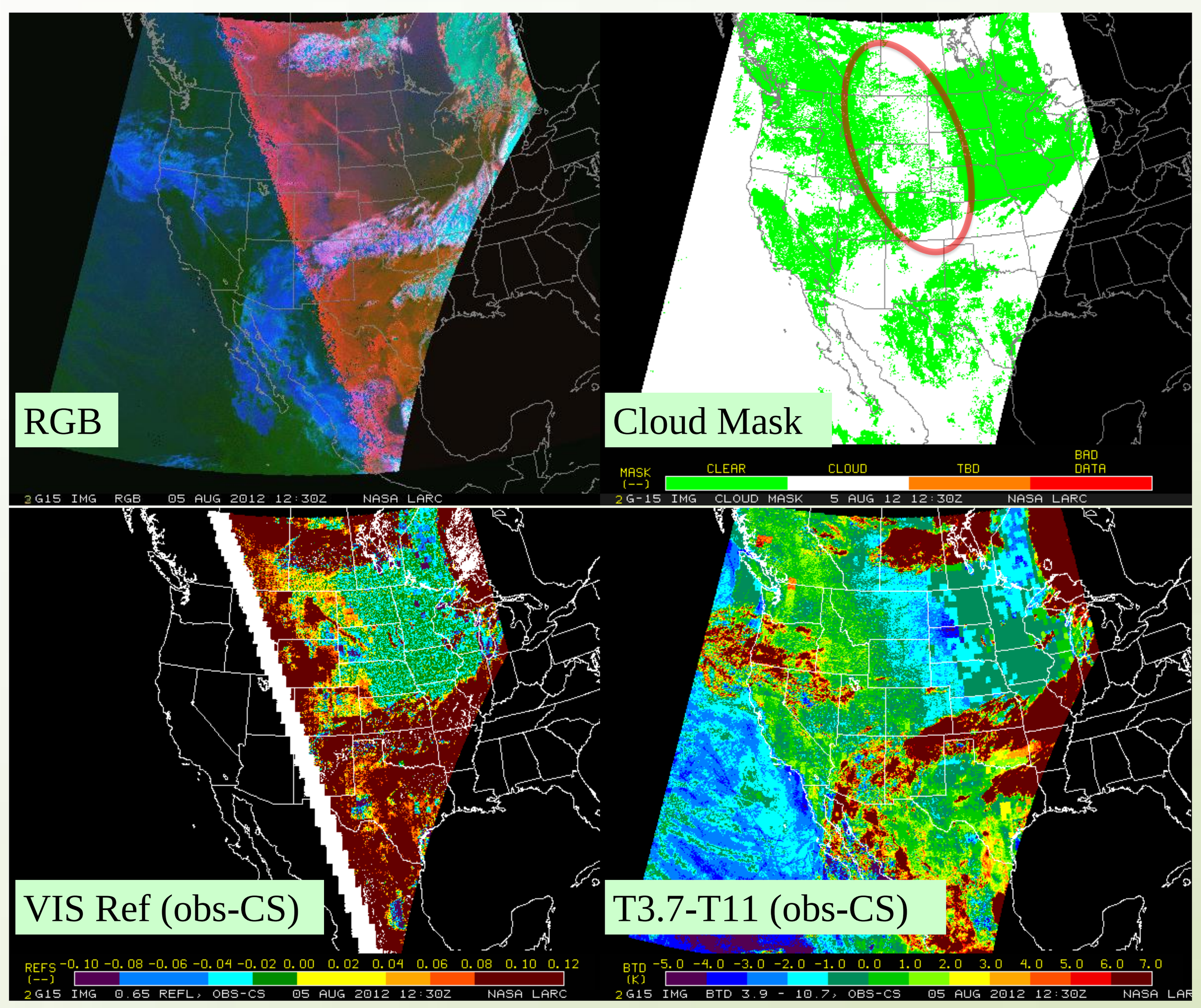
Introduction

Automated cloud detection in satellite imagery is uniquely difficult near the day-night boundary known as the terminator. During the daytime, cloud detection algorithms are typically dependent on accurate clear-sky, top-of-atmosphere (TOA) predictions of reflectance in visible and shortwave-infrared (SIR) channels. However, reflectance is difficult to model at high solar zenith angles (SZA) due to many factors including surface roughness and the presence of snow. These difficulties can lead to false cloud detections from threshold-based cloud detection algorithms. False detections are particularly evident in loops of Geostationary Operational Environmental Satellite (GOES) imagery where the terminator can be observed during its east-to-west progression.



Spatial distributions of GOES-measured reflectance minus predicted reflectance are often noisy, and reflectance is often underestimated for SZA > 80°.

Brightness temperature differences between the GOES 3.9- and 10.8-µm channels, BTD(3.9-10.8), are often underestimated as well due to difficulty estimating the solar component of the 3.9-µm channel.

Nighttime cloud detection methods cannot simply be utilized because they assume that the 3.9-µm channel has no solar component.

Summary

False cloud detections near the day-night terminator result from inadequate modeling of visible and SIR reflectance at high SZA.

Cloud fraction and observed and predicted T11 from prior scans were used to eliminate false cloud detections near the terminator where neither daytime nor nighttime cloud detections can be directly applied.

In loops of satellite imagery, the transition from daytime to nighttime cloud detection methods is much smoother using the presented method in addition to a threshold-based cloud mask.

GLAS comparisons also show that the cloud mask's false-alarm rate is reduced.

Approach

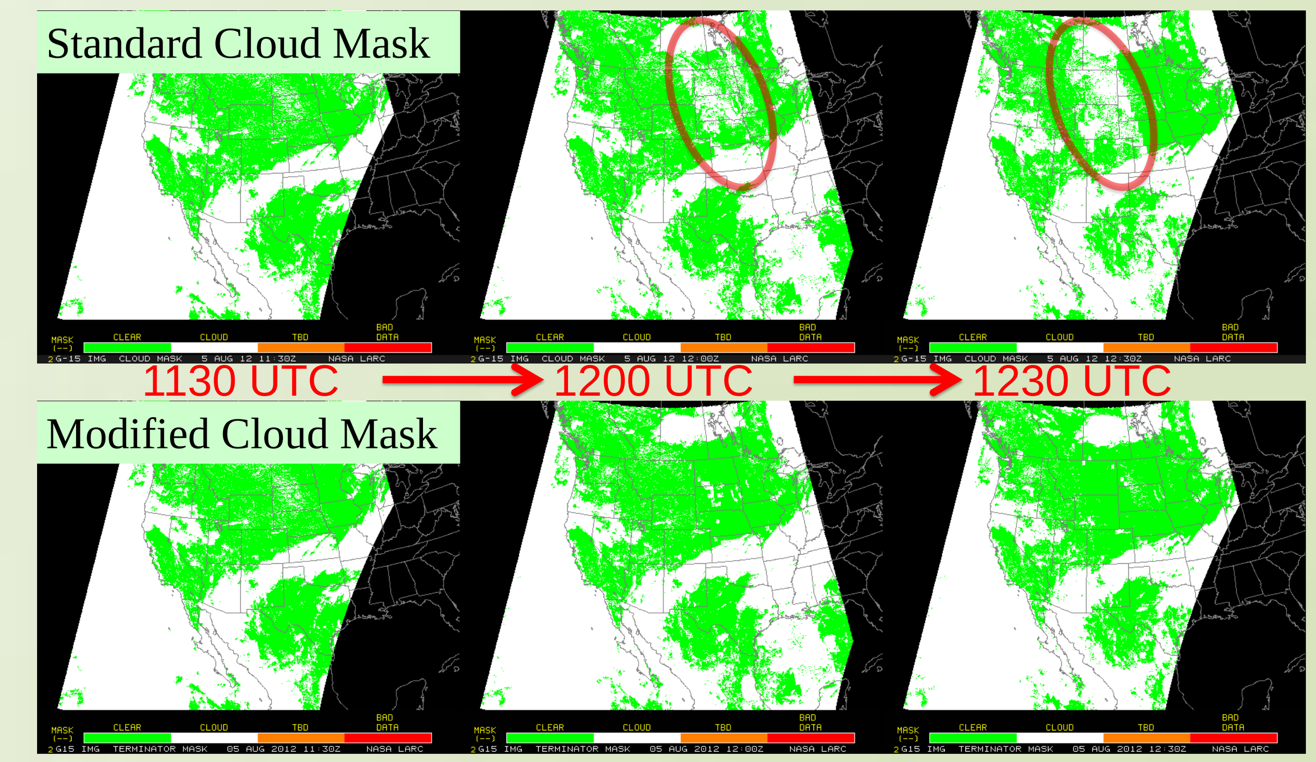
Use cloud fraction, mean clear T11, standard deviation of clear T11, and predicted clear-sky T11 on a 0.5-degree grid from previous image to eliminate false clouds

Assume clear T11 are normally distributed and that mean clear T11 and mean cloudy T11 have different values

Use predicted clear-sky T11 to account for any warming or cooling within gridboxes

Compute confidence score to ensure that observed scene is clear based on previous T11 mean and standard deviation, and previous cloud fraction. Identify pixel as clear if confidence is high enough

Apply algorithm to the daytime side of the terminator where 82.0° < SZA < 88.5°



Algorithm Validation with GLAS

Observations from the Geoscience Laser Altimeter System (GLAS) during Sep-Nov 2003 (laser 2A period) were matched to the nearest imager pixel over the CONUS domain. Differences between the GOES and GLAS scan time were limited to 1 hour or less. Clear/cloudy outcomes are summarized in the table at right as percentage of total number of matches.

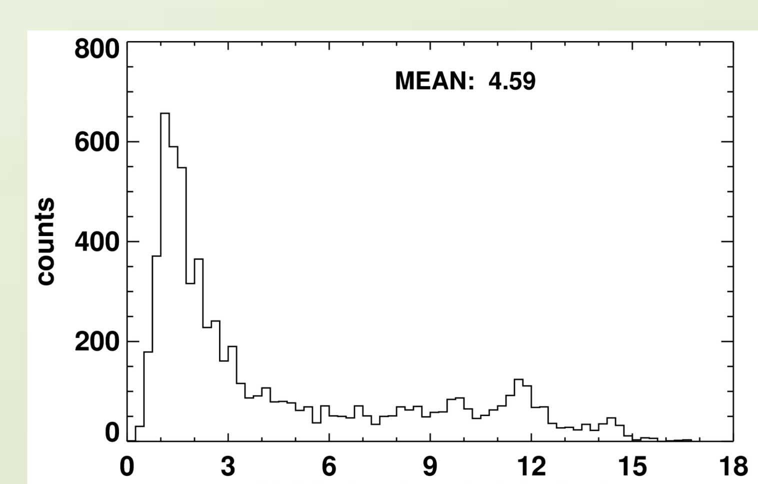
For the terminator region, results are shown for both the standard and the modified cloud mask. Results are also shown for the daytime and nighttime side of the terminator.

		GLAS (532-nm)	
		clear	cloudy
daytime (72 < SZA < 82)	clear	30.1%	10.7%
	cloudy	3.0%	56.2%
nighttime (88.5 SZA < 98.5)	clear	19.6%	13.3%
	cloudy	3.7%	63.4%
terminator (standard mask)	clear	14.3%	7.3%
	cloudy	8.2%	70.3%
terminator (modified mask)	clear	18.1%	10.0%
	cloudy	4.4%	67.5%

The modified cloud mask has increased PC and reduced FAR. Although some real clouds are eliminated, the increased CSI and HSS indicate overall improvement of the cloud mask when compared to the GLAS observations.

	Percent Correct (PC)	False Alarm Rate (FAR)	Critical Success Index (CSI)	Heidke Skill Score (HSS)
daytime	0.863	0.051	0.804	0.71
nighttime	0.830	0.056	0.788	0.58
term. (standard)	0.845	0.105	0.820	0.55
term. (modified)	0.857	0.061	0.825	0.62

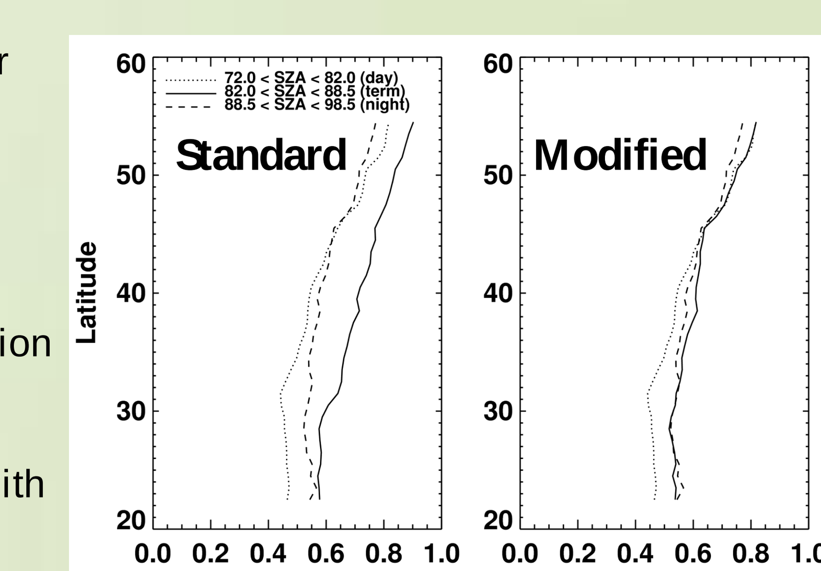
GLAS is generally more sensitive than passive imagers to tenuous cloud layers and has even greater sensitivity at night due to increased signal-to-noise ratio. Low clouds go undetected by the imager retrievals more often than high clouds as shown in the histogram at right.



Zonal mean cloud fraction was computed near the terminator and compared to cloud fraction just before and just after the passing of the terminator (shown at right).

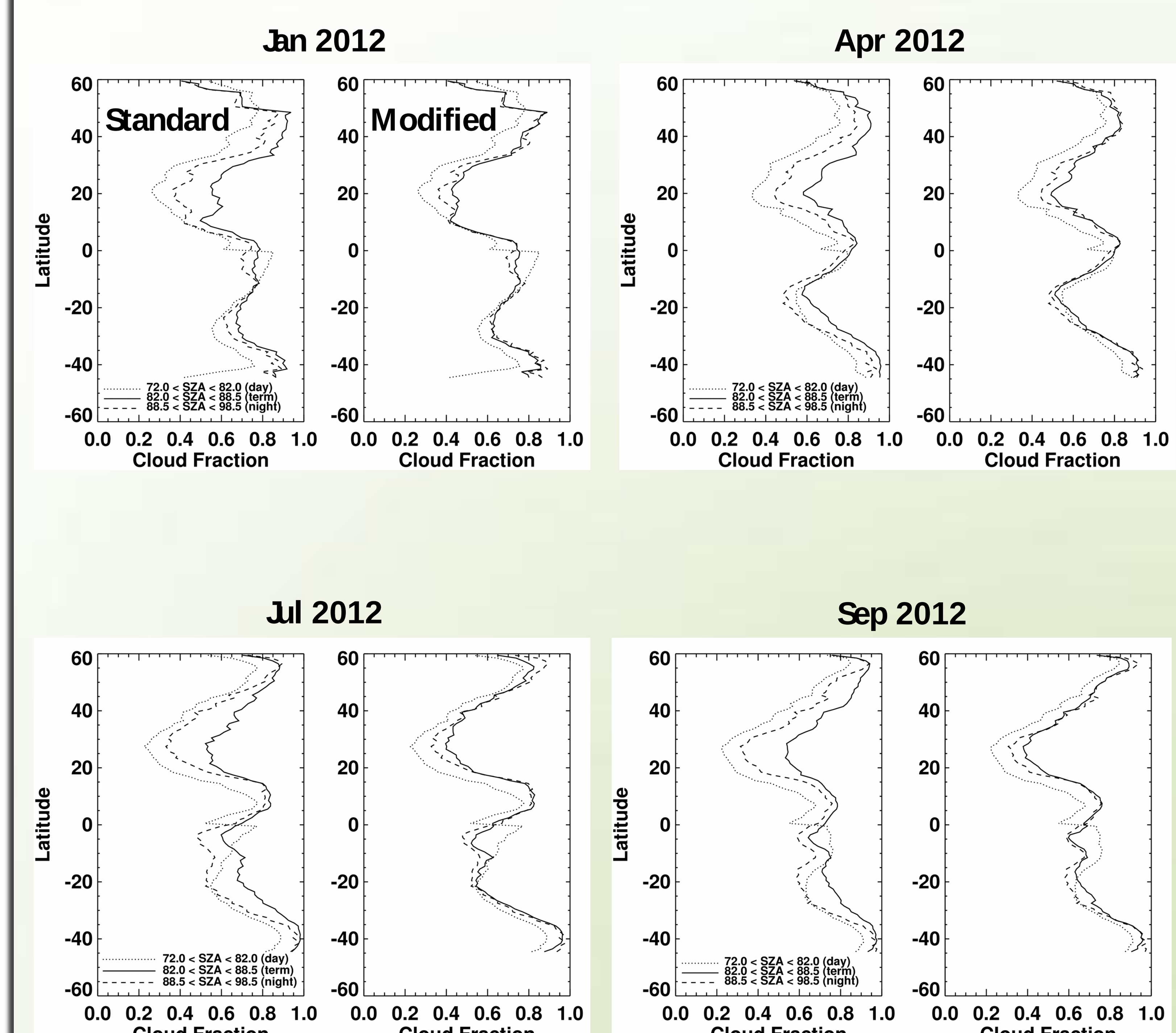
The standard mask overestimates cloud cover compared to the daytime and nighttime detection methods.

The modified cloud mask is more consistent with the daytime and nighttime detection methods.



Full-Disk Results

The present algorithm was applied to full-disk Meteosat-9 imagery for the months of January, April, July, and September 2012. Zonal mean cloud fraction is shown below for each month. The standard cloud mask clearly overestimates cloud fraction compared to the daytime and nighttime cloud detection methods.



Cloud fraction near the terminator is much more consistent with the daytime and nighttime detection methods using the present algorithm.

The algorithm appears robust enough to apply globally to any modern geostationary satellite imager. More validation is currently ongoing with other imagers (e.g., MTSAT-2).

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Contact Information
[redacted]

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