Improvements to Near-Real-Time Cloud Detection Near the Terminator and Impact on Diurnal Trends of Cloud Properties

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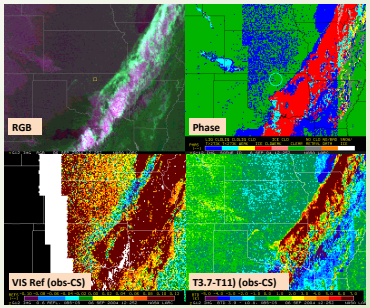
Introduction

Automated cloud detection in satellite imagery near the day/night boundary known as the terminator is uniquely difficult because of the low signal-to-noise ratio in visible (VIS) channels and in the solar component of shortwave-infrared (SIR) channels. Surface features also make clear-sky VIS and SIR reflected radiance difficult to model. False cloud detections may appear near the terminator when predicted clear-sky VIS and SIR radiances are inaccurate as shown below. The retrieved cloud properties for these false detections contaminate the mean macro- and microphysical cloud properties derived over ARM sites. The extent of the contamination is quantified in this study at the ARM SGP site and the AMF site in Germany.



Methods

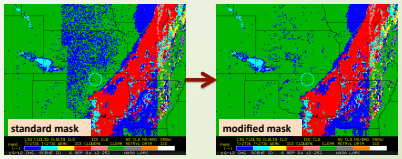
Use cloud fraction, mean clear T11, standard deviation of clear T11, and predicted clear-sky T11 on a 0.5-degree grid from previous image to eliminate false clouds

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 and modify cloud mask if confidence is high enough

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



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Results – Southern Great Plains, Central Facility

The Active Remote Sensing of Clouds (ARSCL) products were used to independently assess the performance of the standard and modified cloud masks near the terminator. The months of September 2004 and October 2008 were characterized by relatively low mean cloud fraction (CF), and these months were chosen for the analysis because of the increased opportunity to reduce false cloud detections. GOES-10 and GOES-12 cloud properties were averaged within a 50-km radius of the SGP, and the ARSCL products were averaged over a 15-minute interval centered at the satellite image times. Results for the daytime and nighttime side of the terminator are also shown for comparison.

GOES and ARSCL CF are summarized in the tables at right in terms of mostly clear (CF < 0.5 and mostly cloudy (CF > 0.5) scenes.

The standard mask has a high false alarm rate (FAR) near the terminator. FAR are significantly lower for the modified mask.

FC = fraction correct
FAR = false alarm rate
CSI = critical success index
HSS = Heidke skill score

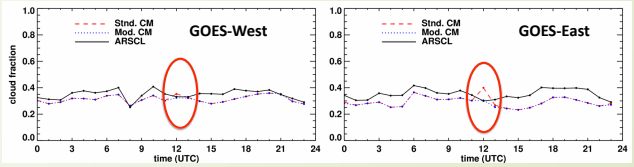
Mean particle size and top height increased by ~6-12% after removal of false cloud detections.

		GOES-West ARSCL		GOES-East ARSCL	
		CF < 0.5	CF > 0.5	CF < 0.5	CF > 0.5
daytime (72 < SZA < 82)	CF < 0.5	66.1%	5.7%	68.7%	8.2%
	CF > 0.5	3.3%	24.9%	1.9%	21.2%
nighttime (88.5 < SZA < 98.5)	CF < 0.5	67.6%	7.1%	68.8%	6.9%
	CF > 0.5	1.9%	23.3%	1.0%	23.4%
terminator (standard mask)	CF < 0.5	61.3%	5.1%	55.9%	6.1%
	CF > 0.5	5.5%	28.1%	10.9%	27.1%
terminator (modified mask)	CF < 0.5	63.0%	5.5%	62.4%	7.9%
	CF > 0.5	3.8%	27.7%	4.4%	25.3%

	GOES-West FC	FAR	CSI	HSS	GOES-East FC	FAR	CSI	HSS
daytime	0.910	0.118	0.734	0.783	0.899	0.084	0.677	0.740
nighttime	0.909	0.077	0.720	0.775	0.921	0.041	0.747	0.802
term. (standard)	0.894	0.165	0.725	0.761	0.830	0.287	0.614	0.629
term. (modified)	0.906	0.122	0.747	0.786	0.878	0.147	0.674	0.717

	GOES-West Standard	Modified	% diff	GOES-East Standard	Modified	% diff
optical depth	5.6	5.4	-3.7	7.2	7.1	-2.1
particle size (microns)	20.3	22.3	+10.1	14.4	15.3	+6.2
effective temperature (K)	271.2	269.7	-0.6	278.2	276.5	-0.6
top height (km)	3.8	4.2	+9.3	2.7	3.1	+12.3

False cloud detections are also evident in plots of hourly mean cloud fraction. Sudden peaks in cloud fraction occur in the GOES data near sunrise and sunset, although the magnitude of the sunset peak is not as large. ARSCL does not show an increase in CF at these times.



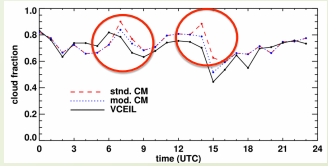
Results – Black Forest, AMF

Cloud properties were analyzed in a similar way for Meteosat 8 and 9 data over the AMF site in Germany. ARSCL products were not available so Vaisala Ceilometer (VCEIL) products were used instead. However, the ceilometer lacks sensitivity to high cirrus clouds. Therefore, ice clouds with a satellite-retrieved altitude > 7 km and optical depth < 6 are excluded from this analysis. Results are shown for December 2007.

		VCEIL CF < 0.5	VCEIL CF > 0.5
daytime (72 < SZA < 82)	CF < 0.5	19.9%	4.6%
	CF > 0.5	8.1%	67.4%
nighttime (88.5 < SZA < 98.5)	CF < 0.5	35.6%	5.8%
	CF > 0.5	2.9%	55.8%
terminator (standard mask)	CF < 0.5	0.9%	0.0%
	CF > 0.5	29.6%	69.6%
terminator (modified mask)	CF < 0.5	15.7%	6.1%
	CF > 0.5	14.8%	63.5%

	FC	FAR	CSI	HSS
daytime	0.873	0.108	0.841	0.672
nighttime	0.913	0.049	0.866	0.820
term. (standard)	0.704	0.298	0.702	0.039
term. (modified)	0.791	0.189	0.753	0.464

	Standard	Modified	% diff
optical depth	8.4	8.1	-3.6
particle size (microns)	25.8	28.6	+11.0
effective temperature (K)	259.1	257.5	-0.6
top height (km)	3.4	3.7	+8.6



The CF peak at sunset is more pronounced at the AMF site. HSS values indicate that the skill of the mask is greatly enhanced near the terminator but still does not quite have the skill of the daytime and nighttime mask.

Changes in the mean cloud properties for the Black Forest AMF are similar to the SGP.

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 detection methods can be directly applied.

Unrealistic peaks in mean cloud fraction near sunrise and sunset are eliminated using the described method. The method demonstrates skill when applied to GOES-10, GOES-11, GOES-12, Meteosat-8, and Meteosat-9 data over the SGP and AMF Black Forest sites and so appears to be fairly robust.

Cloud fraction, particle size, and top height are the most significantly impacted retrievals with percent differences ranging from 6-12%.

False alarm rates for the Meteosat retrievals over the AMF Black Forest site are higher than GOES in part because the Vaisala ceilometer lacks sensitivity for clouds higher than ~7km. A combined radar/lidar product like ARSCL can be used in the future to produce a more complete assessment involving all cloud types.