Comparison of Cloud Properties from CALIPSO-CloudSat and Geostationary Satellite Data

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Introduction

Cloud properties are being derived in near-real time from geostationary satellite imager data for a variety of weather and climate applications and research. Assessment of the uncertainties in each of the derived cloud parameters is essential for confident use of the products. Determination of cloud amount, cloud top height, and cloud layering is especially important for using these real-time products for applications such as aircraft icing condition diagnosis and numerical weather prediction model assimilation. Furthermore, the distribution of clouds as a function of altitude has become a central component of efforts to evaluate climate model cloud simulations. Validation of those parameters has been difficult except over limited areas where ground-based active sensors, such as cloud radars or lidars, have been available on a regular basis. Retrievals of cloud properties are sensitive to the surface background, time of day, and the clouds themselves. Thus, it is essential to assess the geostationary satellite retrievals over a variety of locations. The availability of cloud radar data from CloudSat and lidar data from CALIPSO make it possible to perform those assessments over each geostationary domain at 0130 and 1330 LT. In this paper, CloudSat and CALIPSO data are matched with contemporaneous Geostationary Operational Environmental Satellite (GOES)data. Unlike comparisons with cloud products derived from A-Train imagers, this study considers comparisons of nadir active sensor data with off-nadir retrievals. These matched data are used to determine the uncertainties in cloud-top heights derived from the geostationary satellite data using the Clouds and the Earth's Radiant Energy System (CERES) cloud retrieval algorithms. The results will be useful for constraining the use of the passive retrieval data in models and for improving the accuracy of the retrievals.

Data and Methodology

GOES-12 & GOES-11 VISST Products

GOES 8-km VIS(0.65um), solar-infrared (3.9um), IR (10.8um), and split-window (12.0um or 13um) data were analyzed using the Visible Infrared Solar-Infrared Split-window Technique (VISST: Minnis et al. 1995) over Continental US (CONUS, fig 1. Red box) for Dec 2006 - Jun 2007 period. VISST derives cloud top and base heights, optical depth (TAU), phase, ice water path (IWP), liquid water path (LWP), and cloud temperature. GOES data were obtained from Univ Wisc using McIDAS.

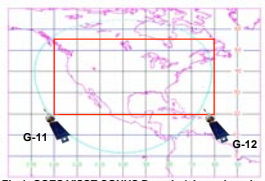


Fig 1. GOES VISST CONUS Domain (shown in red, G11 from 105W-130W, G12 from 60W-105W), and CloudSat/CALIPSO region (shown in cyan)

CloudSat and CALIPSO

2B-GEOPROF-Lidar Products (R04) were obtain from the CloudSat Data Processing Center (DPC) at CSU. This dataset combines CloudSat Radar and CALIPSO Lidar data to best estimate cloud layers (Mace et al.). Shots from lidar are merged in to radar footprint (fig. 2).

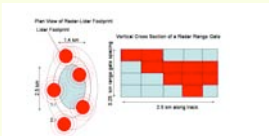
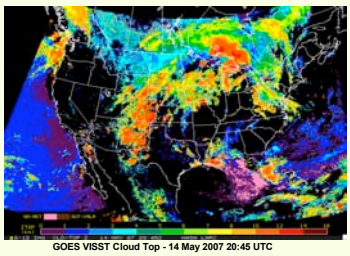


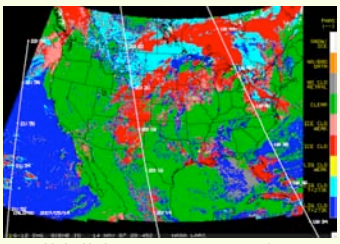
Fig 2. Conceptual view of CPR-Lidar overlap (Courtesy "Level 2 Radar-Lidar GEOPROF Product Proass Description and Interface Control Document, http://www.cloudsat.cira.colostate.edu)

Matching Criteria

- Using CloudSat DPC ordering tool, GEOPROF-Lidar granules are selected if the CloudSat/CALIPSO pass over CONUS (fig 1, cyan circle).
- Radar-Lidar cloud layer products are processed into 8 pixels (20km) along track average. Only all cloudy pixels are used.
- Using Radar-Lidar averages, GOES VISST products are retrieved using closest pixel weighted average of 2x2 8km GOES pixels within the CONUS domain 19N-55N & 60W-130W
- Only single layer (as determined by Radar-Lidar detection flags) are used in the analysis
- Clouds are screened using standard deviation thresholds test on the 8 Radar-Lidar pixel average



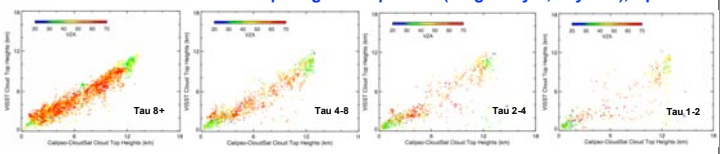
GOES VISST Cloud Top - 14 May 2007 20:45 UTC



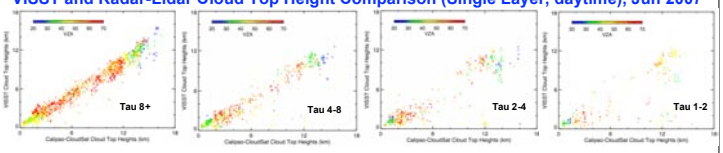
GOES VISST Cloud Phase - 14 May 2007 20:45 UTC

Results

VISST and Radar-Lidar Cloud Top Height Comparison (Single Layer, daytime), Apr 2007



VISST and Radar-Lidar Cloud Top Height Comparison (Single Layer, daytime), Jun 2007



Comparison of GOES and Radar-Lidar Derived Cloud Top Height

Night, Tau < 8

Mon	N	Slope	Offset	R2	CCm	Vm	Bias	Rms
Dec	747	0.761	0.204	0.769	5.93	4.72	-1.21	2.60
Jan	938	0.752	0.246	0.764	4.16	3.38	-0.78	1.97
Feb	516	0.426	1.04	0.364	3.39	2.48	-0.91	2.57
Mar								
Apr	721	0.694	0.441	0.701	5.20	4.05	-1.15	2.77
May	1020	0.517	0.809	0.430	6.97	4.41	-2.56	4.9
Jun	593	0.518	0.946	0.474	8.47	5.33	-3.14	5.50

Night, 4 < Tau <= 8

Mon	N	Slope	Offset	R2	CCm	Vm	Bias	Rms
Dec	473	0.666	0.326	0.613	7.08	5.04	-1.21	3.68
Jan	836	0.620	1.003	0.501	5.76	4.57	-0.78	3.10
Feb	350	0.592	0.968	0.465	6.55	4.85	-1.7	3.67
Mar								
Apr	649	0.437	1.691	0.225	7.52	4.97	-1.16	4.64
May	1091	0.280	2.287	0.105	8.87	4.74	-2.56	6.49
Jun	387	0.429	1.508	0.250	8.56	5.31	-3.14	5.50

Night, 2 < Tau <= 4

Mon	N	Slope	Offset	R2	CCm	Vm	Bias	Rms
Dec	365	0.733	0.926	0.625	6.24	5.50	-1.21	2.49
Jan	607	0.701	1.361	0.593	6.23	5.02	-0.78	2.33
Feb	247	0.573	2.11	0.38	6.91	6.07	-0.84	3.13
Mar								
Apr	422	0.595	1.70	0.363	7.25	6.02	-1.15	3.19
May	472	0.228	3.428	0.065	7.85	5.22	-2.56	5.38
Jun	218	0.292	2.300	0.124	8.08	4.66	-3.14	6.48

Night, 1 < Tau <= 2

Mon	N	Slope	Offset	R2	CCm	Vm	Bias	Rms
Dec	200	0.688	1.360	0.478	7.12	6.23	-1.21	2.96
Jan	229	0.670	1.849	0.494	9.40	8.47	-0.78	2.60
Feb	124	0.454	3.55	0.242	7.48	6.94	-0.54	3.63
Mar								
Apr	254	0.872	0.680	0.728	7.93	7.60	-1.15	1.72
May	261	0.394	3.510	0.168	8.04	6.68	-2.56	4.71
Jun	94	0.385	3.496	0.173	9.29	7.07	-3.14	5.92

Night, 0 < Tau <= 1

Mon	N	Slope	Offset	R2	CCm	Vm	Bias	Rms
Dec	157	0.934	-0.049	0.712	5.76	5.33	-1.21	2.41
Jan	241	0.655	1.972	0.291	3.65	4.36	-0.78	3.63
Feb	118	0.765	1.62	0.518	8.76	8.32	-0.44	3.22
Mar								
Apr	163	0.620	3.218	0.421	7.34	7.77	-1.16	2.93
May	200	0.726	1.740	0.484	7.61	7.26	-2.56	3.98
Jun	60	0.610	2.935	0.409	7.51	7.52	-3.14	4.71

Daytime, Tau < 8

Mon	N	Slope	Offset	R2	CCm	Vm	Bias	Rms
Dec	2961	0.762	0.571	0.916	5.88	5.05	-0.83	1.65
Jan	4792	0.741	0.564	0.867	5.46	4.63	-0.83	1.70
Feb	2219	0.675	0.70	0.737	5.47	4.39	-1.08	2.02
Mar								
Apr	3271	0.729	0.511	0.904	6.22	5.05	-1.17	1.76
May	3427	0.764	0.552	0.923	6.86	5.79	-1.07	1.72
Jun	1609	0.826	0.210	0.961	6.96	5.96	-1.00	1.51

Daytime, 4 < Tau <= 8

Mon	N	Slope	Offset	R2	CCm	Vm	Bias	Rms
Dec	866	0.731	0.346	0.841	5.59	4.44	-0.83	2.01
Jan	1444	0.701	0.253	0.802	4.99	3.76	-0.83	2.12
Feb	921	0.614	0.773	0.596	5.94	4.38	-1.56	2.79
Mar								
Apr	1273	0.728	0.390	0.891	5.47	4.37	-1.17	1.87
May	1437	0.733	0.312	0.893	4.90	3.90	-1.07	1.84
Jun	657	0.738	0.145	0.884	5.07	3.99	-1.00	2.07

Daytime, 2 < Tau <= 4

Mon	N	Slope	Offset	R2	CCm	Vm	Bias	Rms
Dec	652	0.687	0.234	0.760	5.73	4.17	-0.83	2.71
Jan	1205	0.753	0.131	0.815	5.35	4.16	-0.83	2.22
Feb	595	0.549	0.713	0.446	5.85	3.89	1.91	3.58
Mar								
Apr	821	0.710	0.249	0.790	5.63	4.24	-1.17	2.47
May	1072	0.723	0.194	0.788	5.88	4.44	-1.07	2.61
Jun	444	0.674	0.705	0.705	4.50	3.27	-1.00	3.27

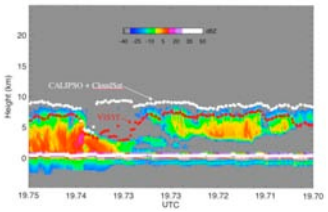
Daytime, 1 < Tau <= 2

Mon	N	Slope	Offset	R2	CCm	Vm	Bias	Rms
Dec	430	0.689	0.188	0.747	6.69	4.80	-0.83	3.05
Jan	654	0.673	0.297	0.740	5.25	3.83	-0.83	2.77
Feb	260	0.407	1.23	0.289	6.17	3.74	2.43	4.55
Mar								
Apr	437	0.641	0.345	0.695	6.85	4.74	-1.17	3.44
May	585	0.620	0.587	0.631	6.77	4.79	-1.07	3.55
Jun	250	0.666	0.216	0.624	7.64	5.31	-1.00	3.89

Daytime, 0 < Tau <= 1

Mon	N	Slope	Offset	R2	CCm	Vm	Bias	Rms
Dec	278	0.442	1.267	0.459	6.18	4.00	-0.83	4.21
Jan	409	0.400	1.604	0.426	4.96	3.98	-0.83	3.67
Feb	160	0.461	1.34	0.486	5.34	3.8	1.54	3.83
Mar								
Apr	258	0.414	2.526	0.298	6.38	5.17	-1.17	4.34
May	434	0.444	2.058	0.334	6.56	4.97	-1.07	4.36
Jun	173	0.514	2.222	0.479	7.13	5.89	-1.00	4.05

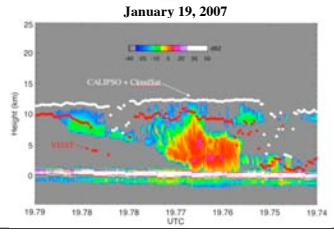
March 1, 2007



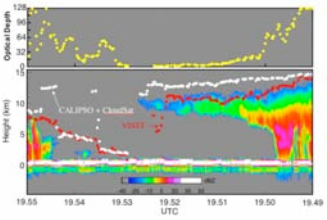
Tau >= 2, all months

CTop Height	Day/night	CCmean	Vmean	Bias	N
0 < CTH <= 4	Day	1.99	2.01	0.02	12294
4 < CTH <= 8	Day	5.84	4.52	-1.32	6720
CTH > 8	Day	10.98	8.31	-2.67	9190
0 < CTH <= 4	Night	1.83	2.02	0.19	3776
4 < CTH < 8	Night	5.26	5.47	-0.79	1631
CTH > 8	Night	11.19	7.56	-3.63	4078

January 19, 2007



May 6, 2007



Summary

- Preliminary results from GOES and GEOPROF-Lidar products shows good cloud height correlations for single layer clouds
- No significant viewing zenith angle dependency can detected from GOES cloud heights retrievals
- Larger bias for clouds with optical depth of < 2
- Daytime VISST cloud height retrieval slightly better than nighttime
- Cloud height comparison show better agreement in low cloud (bias -0.03), mid level bias is -1.3, and high clouds has larger differences (bias -2.7)
- The CERES multi-layer cloud detection method will be evaluated in the future
- Correction needed for VISST cloud heights for optically thick clouds