"Evaluation of multi-layer cloud detection based on active-passive sensors"

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Outline

- Motivation
- Data and Methodology
- Results
- Conclusions and Future work

Motivation

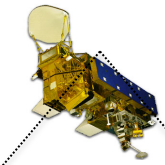
Why is cloud overlapping important?

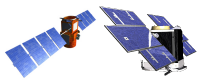
- Knowledge of cloud vertical structure is important for a variety of weather and climate related applications such as:
  - Cloud overlap variations greatly influence atmospheric heating/cooling rates, with important implications for the radiative balance of the surface-troposphere system, global circulation and precipitation
  - Aviation and weather applications
- One of the most important consequences of ignoring the multilayer clouds is the introduction of errors in deducing the radiative impact of clouds.
- Evaluate two different ways to estimate the presence of multilayered clouds based on the instrumentation (active and passive sensors).

Data used

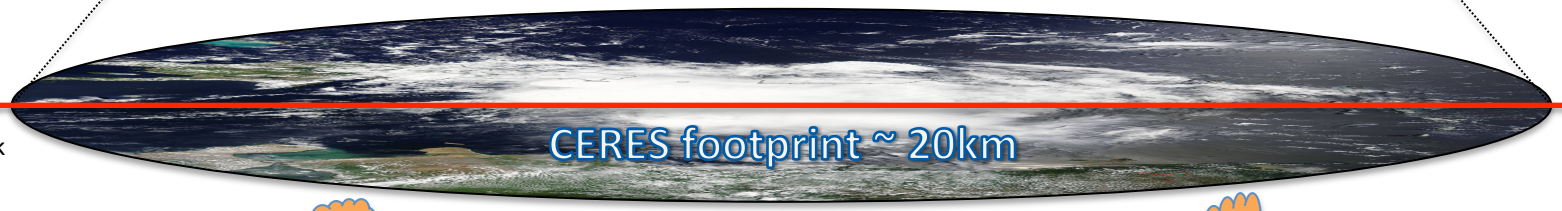
- CALIPSO-CloudSat (CLCS): Cloud and aerosol mask in CALIPSO-CloudSat-CERES-MODIS (CCCM) release C1.
  - Clouds are grouped up to 16 groups by cloud coverage and up to 6 overlapped layers (*Kato et al 2010*).
  - All the multilayered cloud groups are averaged and weighed by CF.
- The Multilayer Cloud Footprint (MCF) algorithm(*Fu-Lung et al. 2010*) in CERES SSF-Edition4: This algorithm is based on MODIS and uses the CO_2-slicing technique to locate high thin clouds. Then it uses the IR and VIS observations to determine optical depths in two cloud layers.
- The MCF cases selected are only over CLCS ***ground track*** and have cloud properties derived from the ***standard cloud algorithm***.
- The data for MCF (SSF Edition 4) in the CCCM Release C1 is currently only available for January, April, July and October 2010.

Methodology





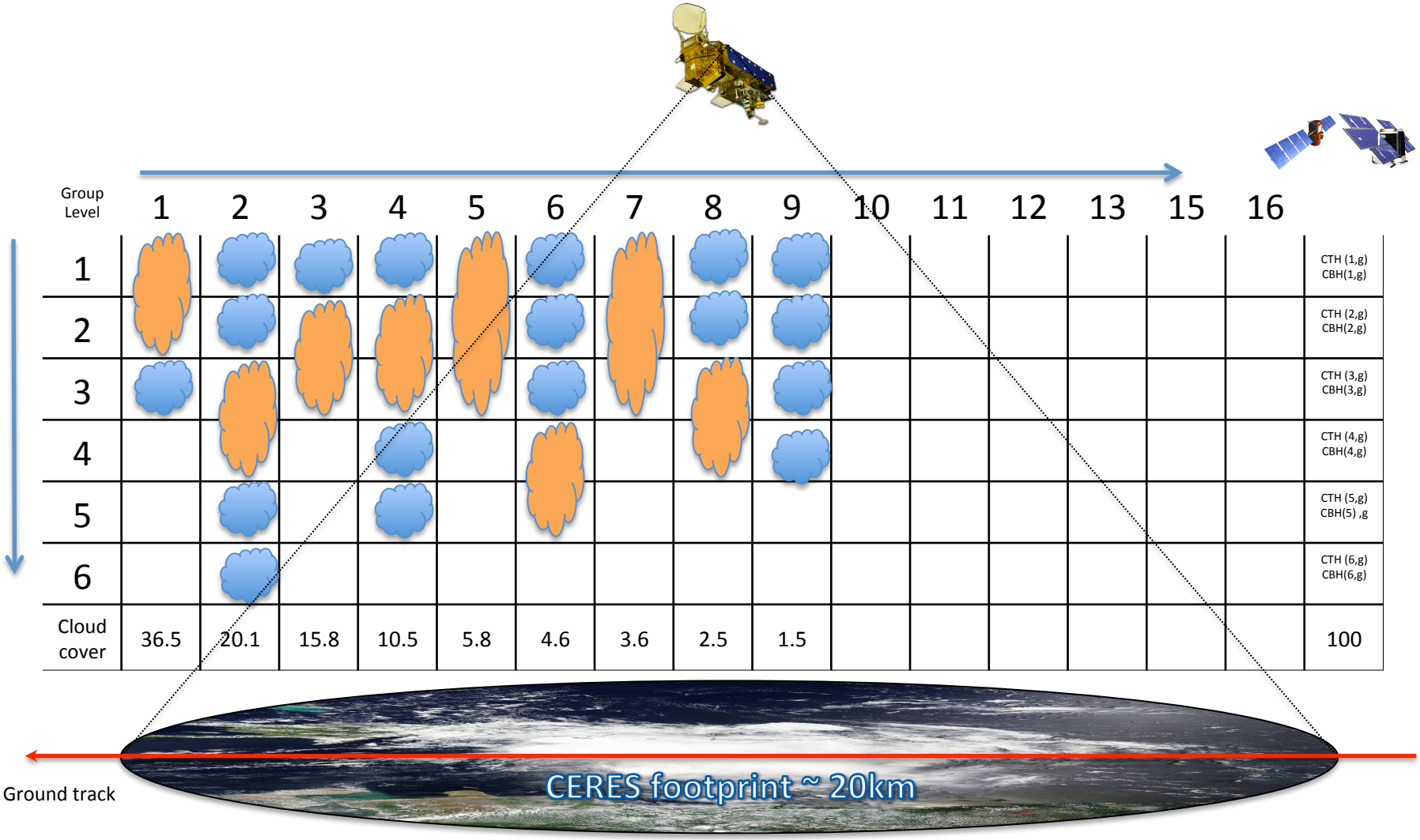
Group Level	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	
1																CTH (1,g) CBH(1,g)
2																CTH (2,g) CBH(2,g)
3																CTH (3,g) CBH(3,g)
4																CTH (4,g) CBH(4,g)
5																CTH (5,g) CBH(5,g)
6																CTH (6,g) CBH(6,g)
Cloud cover	36.5	20.1	15.8	10.5	5.8	4.6	3.6	2.5	1.5							100



Ground track

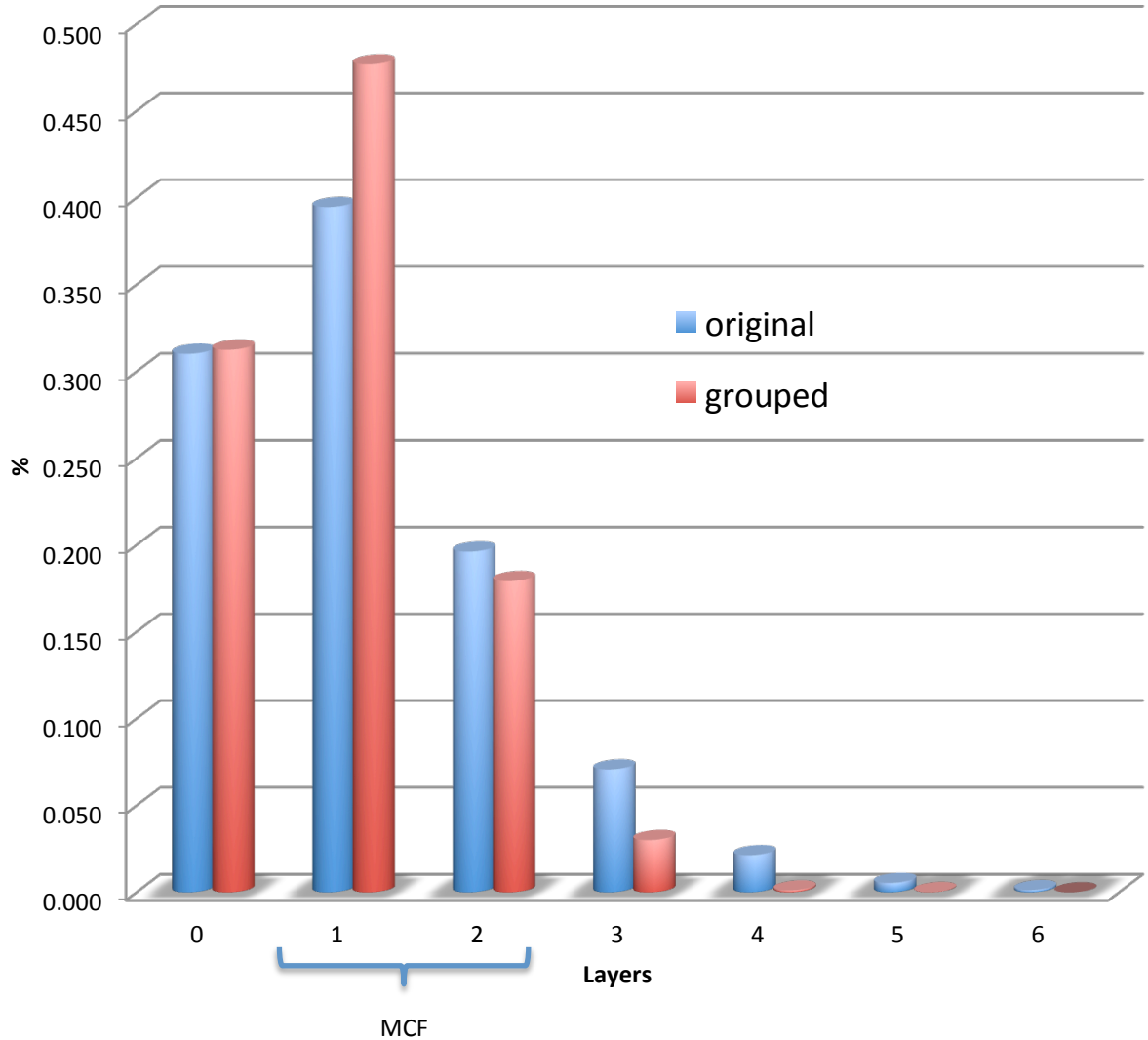
If CTH(i+1)-CBH(i)<1km ➔ New cloud with: CTH(i),CBH(i+1)

Methodology



New cloud with: CTH(i),CBH(i+1)

Frequency of overlapped layers for CLCS: 201004
Original~Reduced by 1Km gap cloud separation



Results

Evaluation of MCF algorithm for:

- CLCS single layer only
- CLCS 2 overlapped layers

CALIPSO-CloudSat case #1 (SINGLE)

- Daytime (SZA<78°) footprints and no ice surface
  - CLCS single cloud layer, CTP<600 hPa

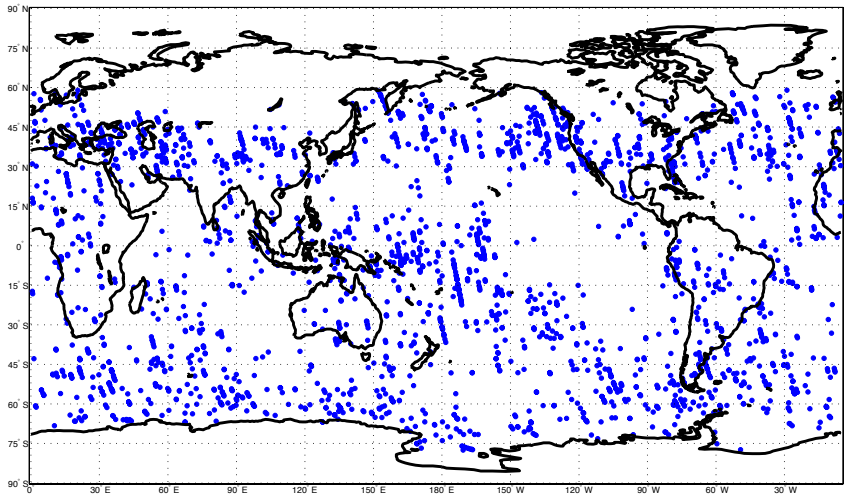
CALIPSO-CloudSat case #1 (SINGLE)

			CLCS	MCF			
	total	daytime	single	single	overlap	clear	
footprints	801526	341091	2402	1031	1368	3	January
%	100	42.56	0.30	0.13	0.17	0.00	
	%	100	0.70	0.30	0.40	0.00	
		%	100	**42.92**	**56.95**	0.12	
footprints	803669	342387	5915	3008	2862	45	April
%	100	42.60	0.74	0.37	0.36	0.01	
	%	100	1.73	0.88	0.84	0.01	
		%	100	**50.85**	**48.39**	0.76	
footprints	803531	343838	4606	2083	2504	19	July
%	100	42.79	0.57	0.26	0.31	0.00	
	%	100	1.34	0.61	0.73	0.01	
		%	100	**45.22**	**54.36**	0.41	
footprints	811242	340847	5396	2495	2891	10	October
%	100	42.02	0.67	0.31	0.36	0.00	
	%	100	1.58	0.73	0.85	0.00	
		%	100	**46.24**	**53.58**	0.19	

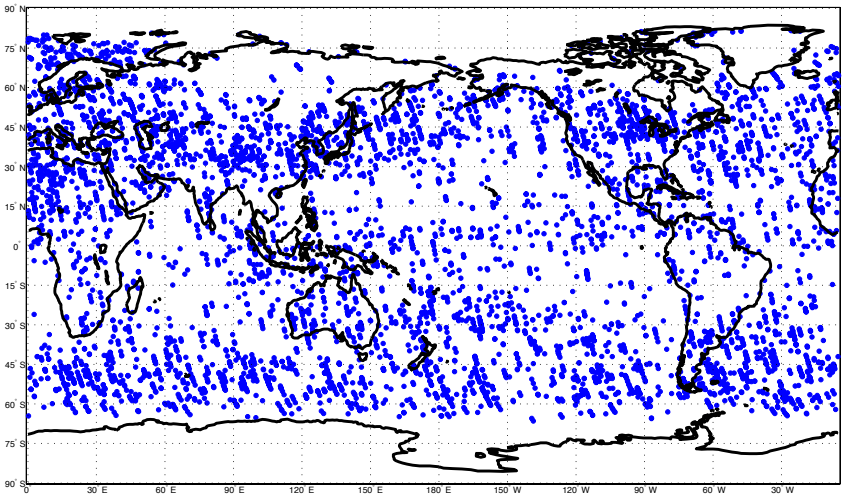
MCF		
single	overlap	clear
46.31	**53.32**	0.37

- CLCS single: no surface ice and CTP<600hPa

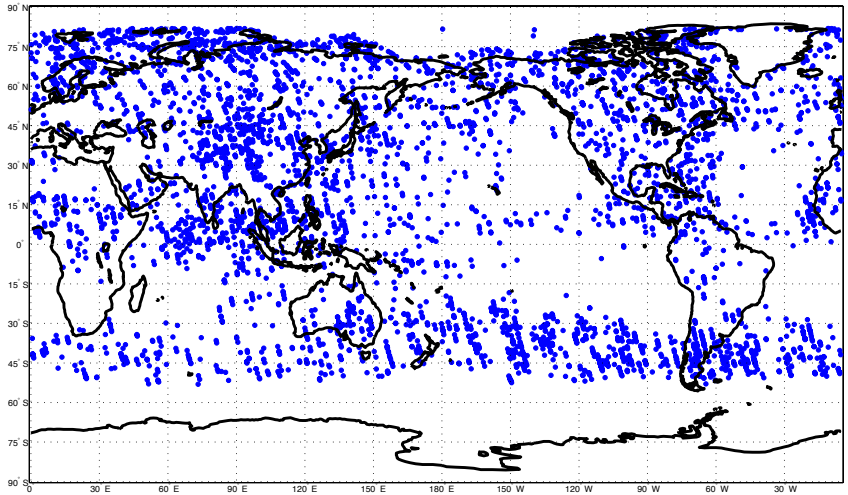
(201001) : CLCS single (CTP<600 hPa)
Number of cases: 2402



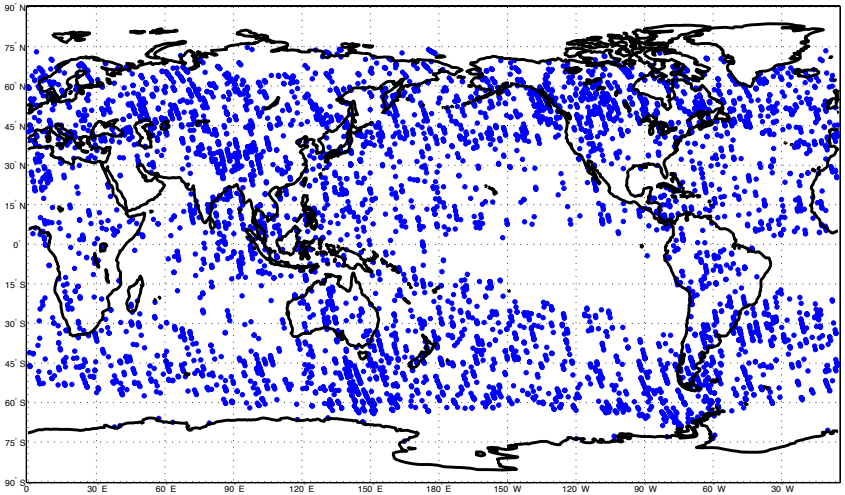
(201004) : CLCS single (CTP<600 hPa)
Number of cases: 5915



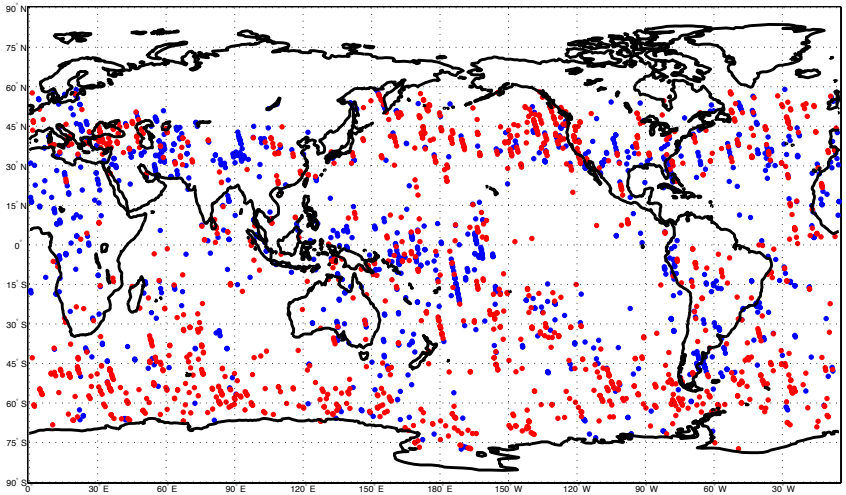
(201007) : CLCS single (CTP<600 hPa)
Number of cases: 4606



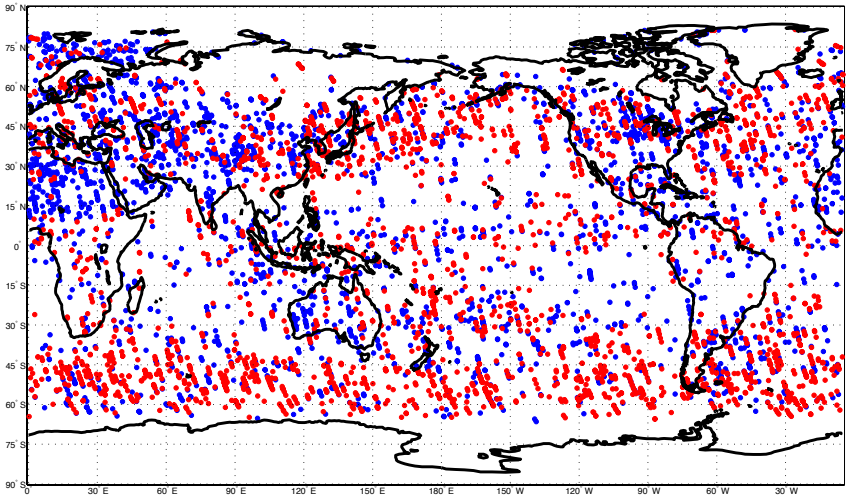
(201010) : CLCS single (CTP<600 hPa)
Number of cases: 5396



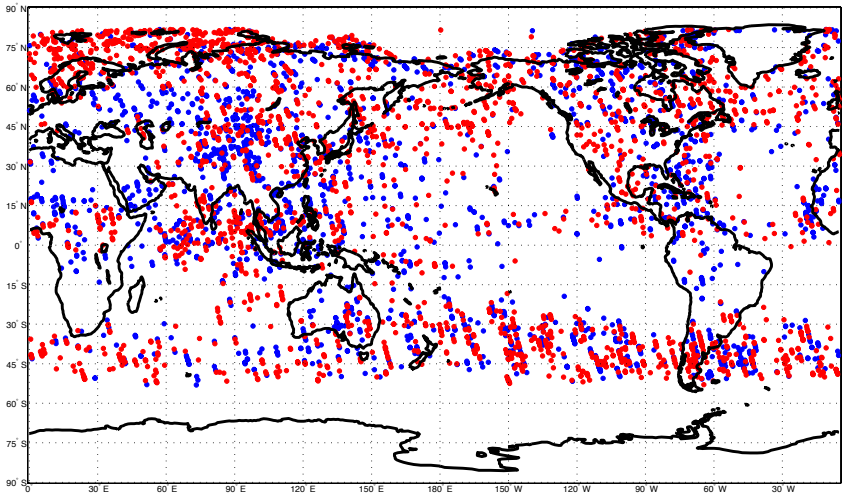
(201001) : MCF single (blue) and multilayer (red)
# of cases: 1031 single, 1368 multi



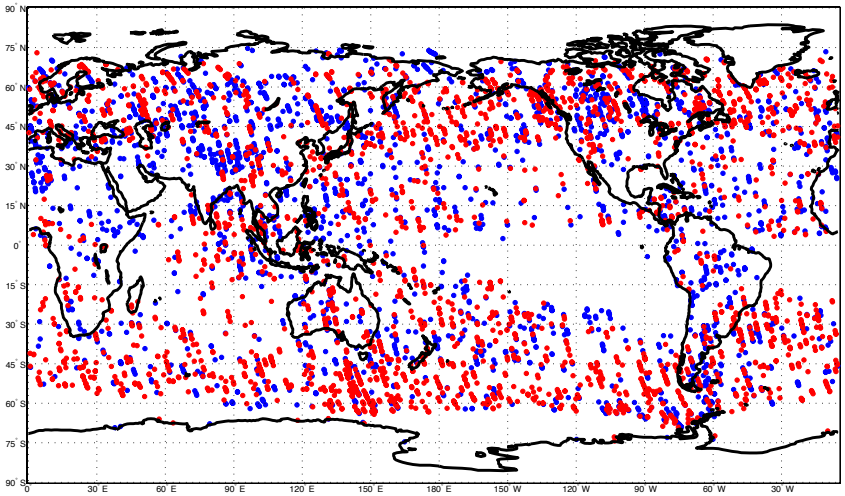
(201004) : MCF single (blue) and multilayer (red)
# of cases: 3008 single, 2862 multi

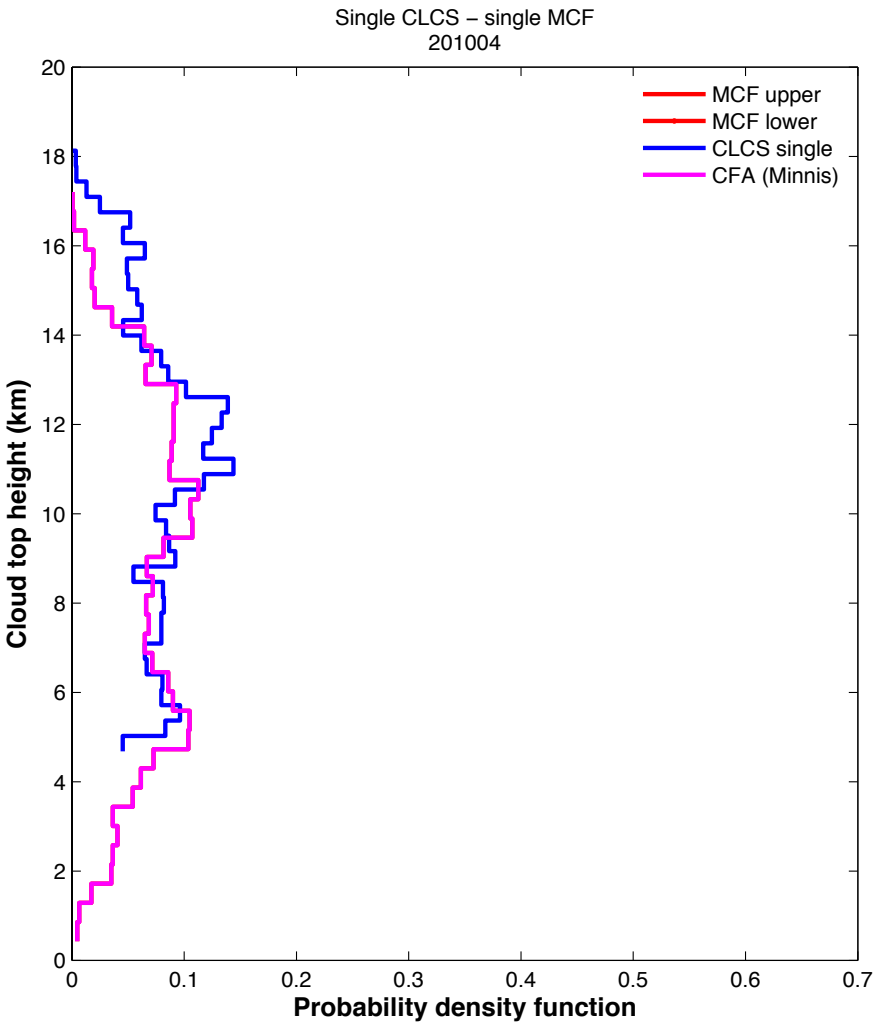


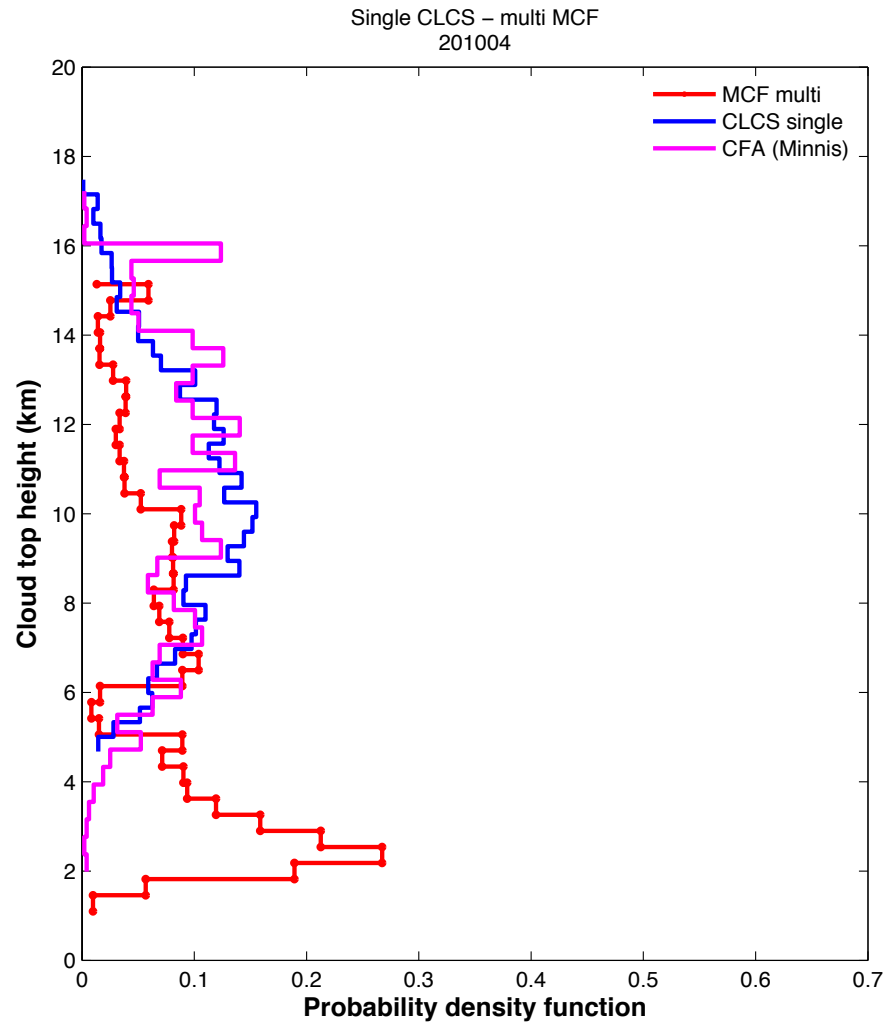
(201007) : MCF single (blue) and multilayer (red)
# of cases: 2083 single, 2504 multi



(201010) : MCF single (blue) and multilayer (red)
# of cases: 2495 single, 2891 multi




Single CLCS – single MCF
201004
MCF upper
MCF lower
CLCS single
CFA (Minnis)
Cloud top height (km)
Probability density function
0
2
4
6
8
10
12
14
16
18
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7


Single CLCS – multi MCF
201004
MCF multi
CLCS single
CFA (Minnis)
Cloud top height (km)
Probability density function
0
2
4
6
8
10
12
14
16
18
20
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7

CALIPSO-CloudSat case #2 (MULTILAYER)

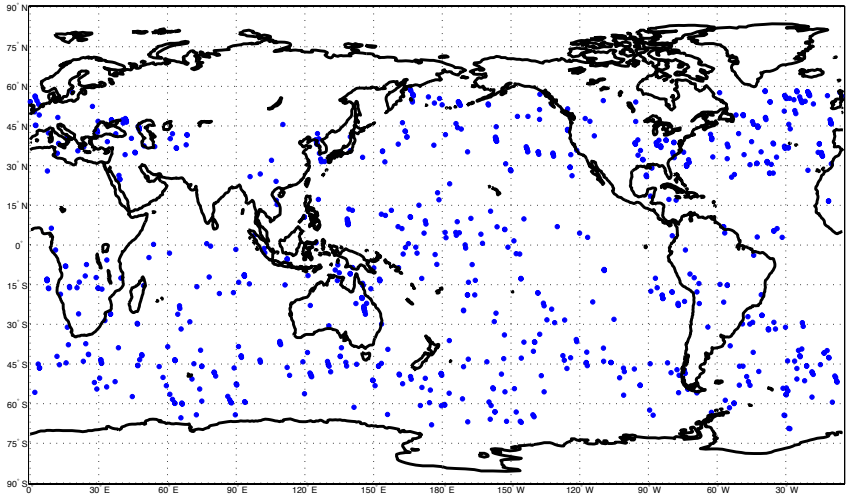
- Daytime (SZA<78°) footprints and no ice surface
    - CLCS with 2 overlapped cloud layers

			CLCS		MCF			
	total	daytime	2 overlapped	FL multi	single	overlap	clear	
footprints	801526	341091	11126	766	110	656	0	January
%	100	42.56	1.39	0.10	0.01	0.08	0.00	
	%	100	3.26	0.22	0.03	0.19	0.00	
		%	100	6.88	0.99	5.90	0.00	
				100	**14.36**	**85.64**	0.00	
footprints	803669	342387	14842	1856	361	1495	0	April
%	100	42.60	1.85	0.23	0.04	0.19	0.00	
	%	100	4.33	0.54	0.11	0.44	0.00	
		%	100	12.51	2.43	10.07	0.00	
				100	**19.45**	**80.55**	0.00	
footprints	803531	343838	11627	1516	272	1244	0	July
%	100	42.79	1.45	0.19	0.03	0.15	0.00	
	%	100	3.38	0.44	0.08	0.36	0.00	
		%	100	13.04	2.34	10.70	0.00	
				100	**17.94**	**82.06**	0.00	
footprints	811242	340847	13197	1569	314	1255	0	October
%	100	42.02	1.63	0.19	0.04	0.15	0.00	
	%	100	3.87	0.46	0.09	0.37	0.00	
		%	100	11.89	2.38	9.51	0.00	
				100	**20.01**	**79.99**	0.00	

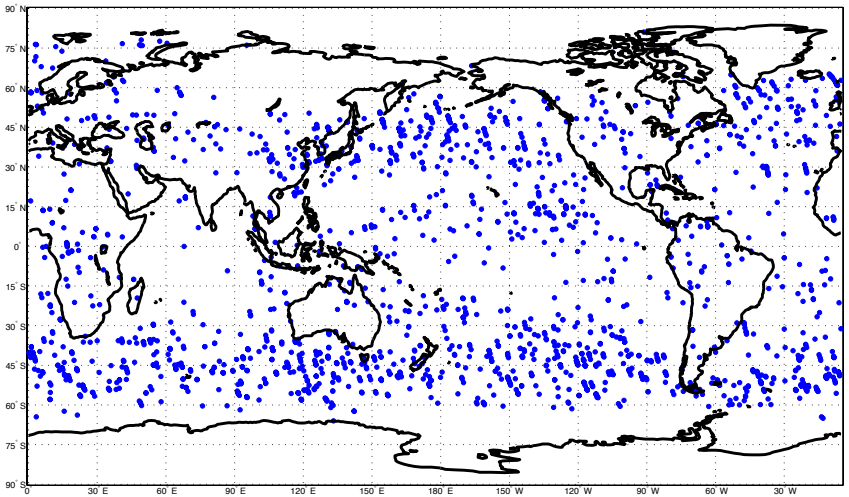
MCF		
single	overlap	clear
17.94	82.06	0.00

- CLCS 2 overlapped: no surface ice
- FL multi: CTP upper<600 hPa, ΔCTP>100 hPa, COD upper layer >0.3

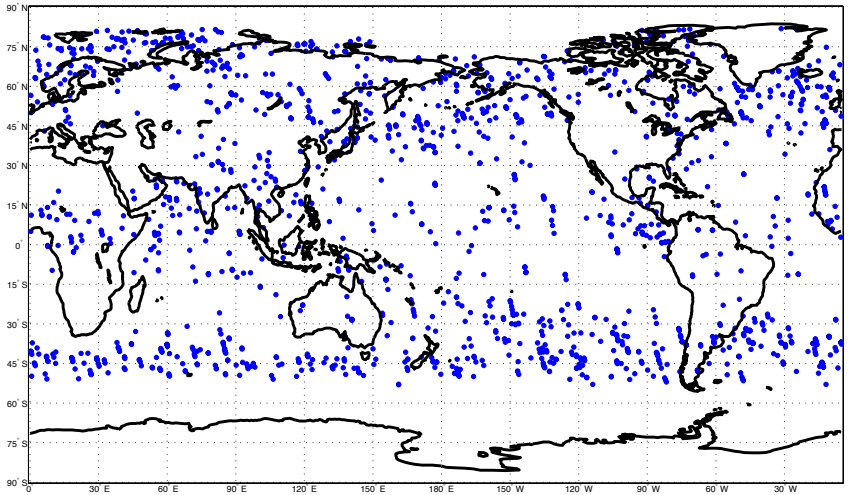
(201001) : CLCS 2 overlapped multilayer, COD(upper>0.3)
Number of cases: 766



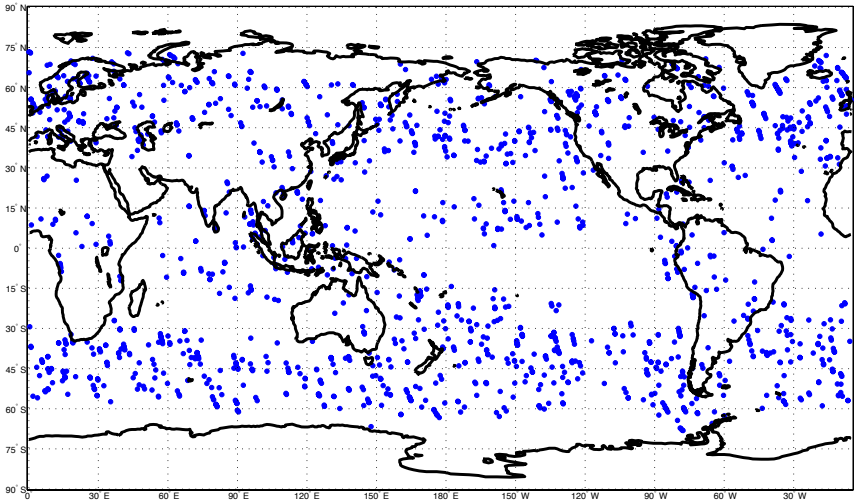
(201004) : CLCS 2 overlapped multilayer, COD(upper>0.3)
Number of cases: 1856



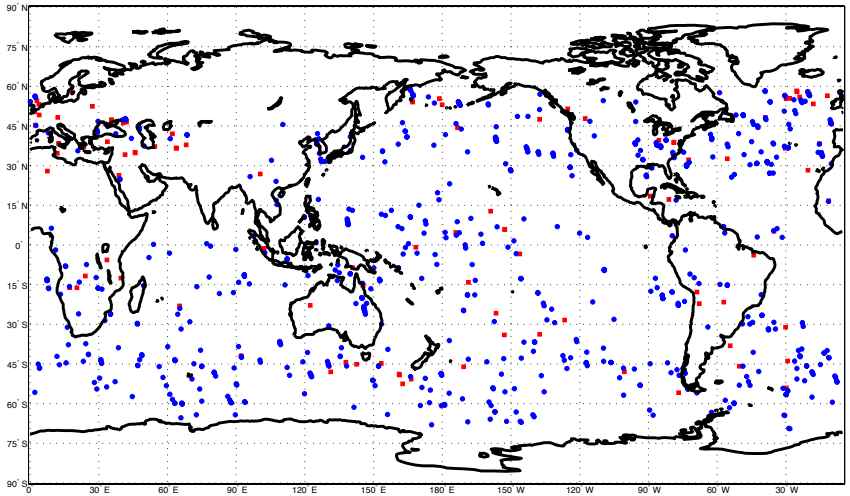
(201007) : CLCS 2 overlapped multilayer, COD(upper>0.3)
Number of cases: 1516



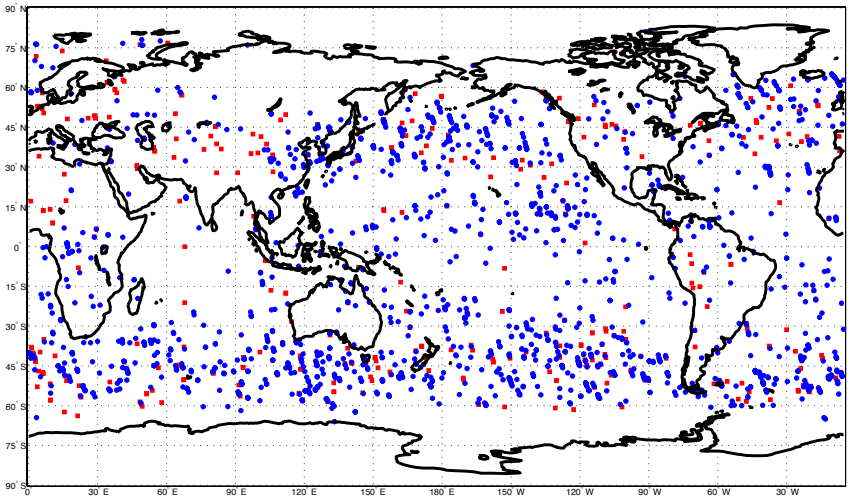
(201010) : CLCS 2 overlapped multilayer, COD(upper>0.3)
Number of cases: 1569



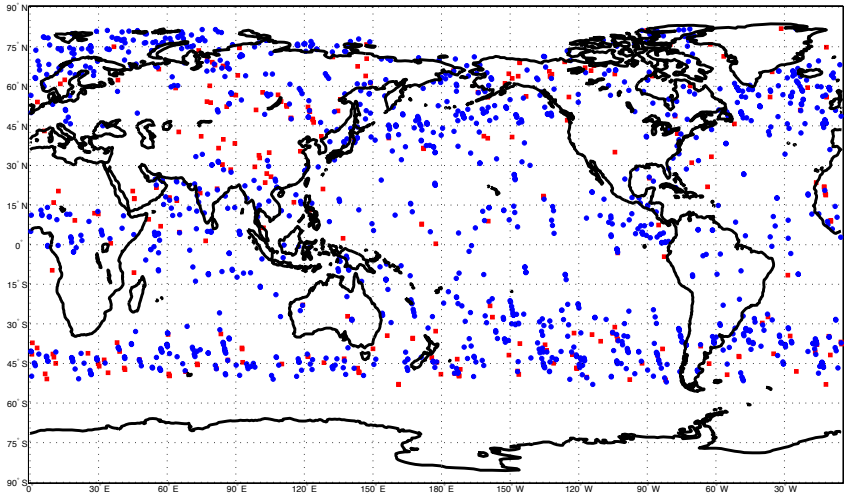
(201001) : MCF single (red) and multilayer (blue)
# of cases: 110 single, 656 multi



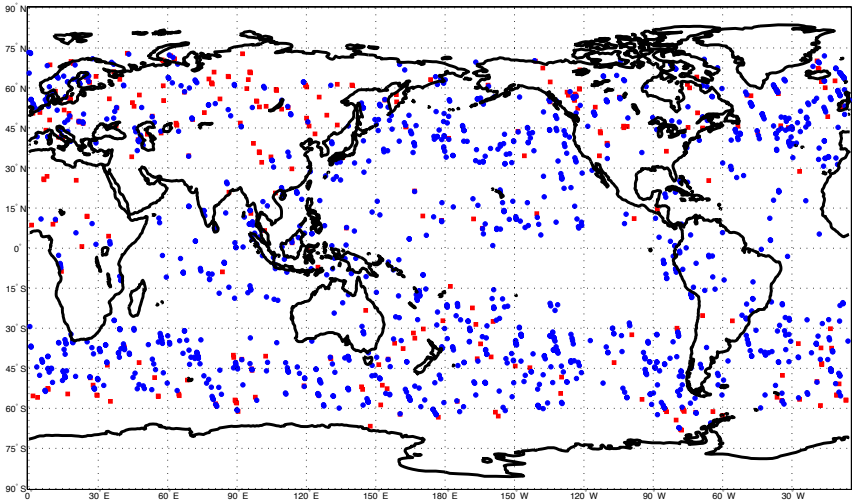
(201004) : MCF single (red) and multilayer (blue)
# of cases: 361 single, 1495 multi

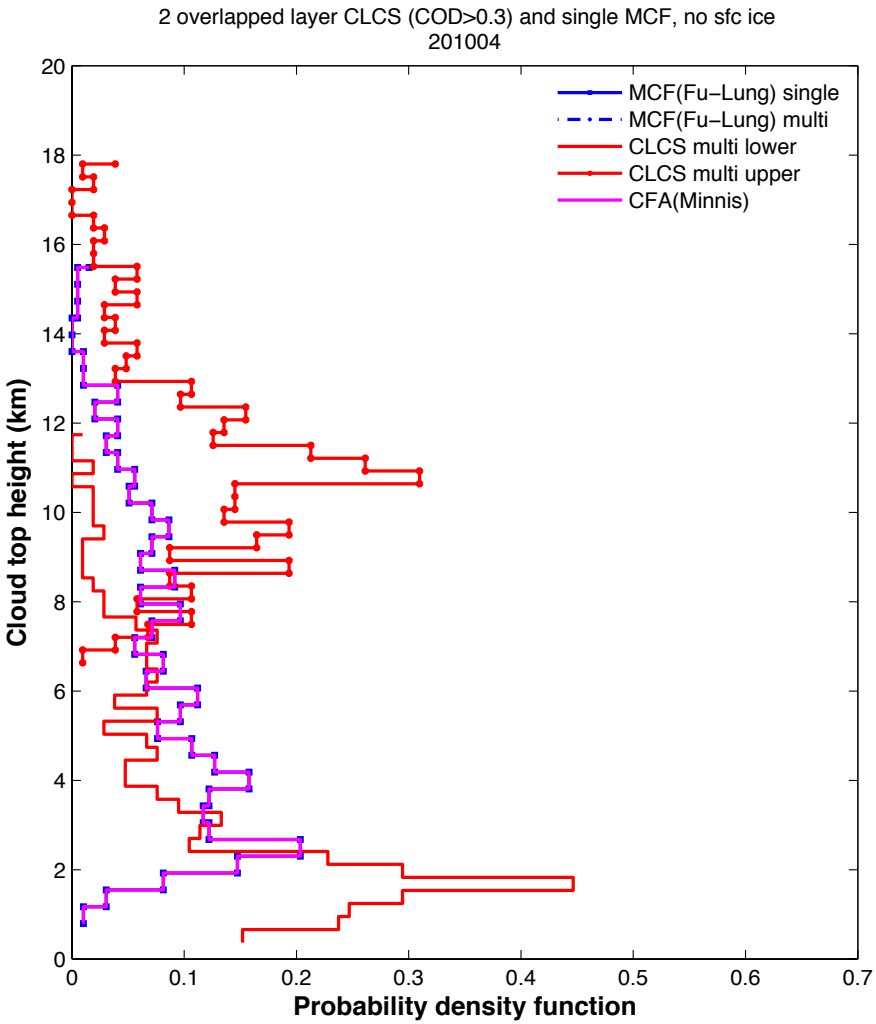


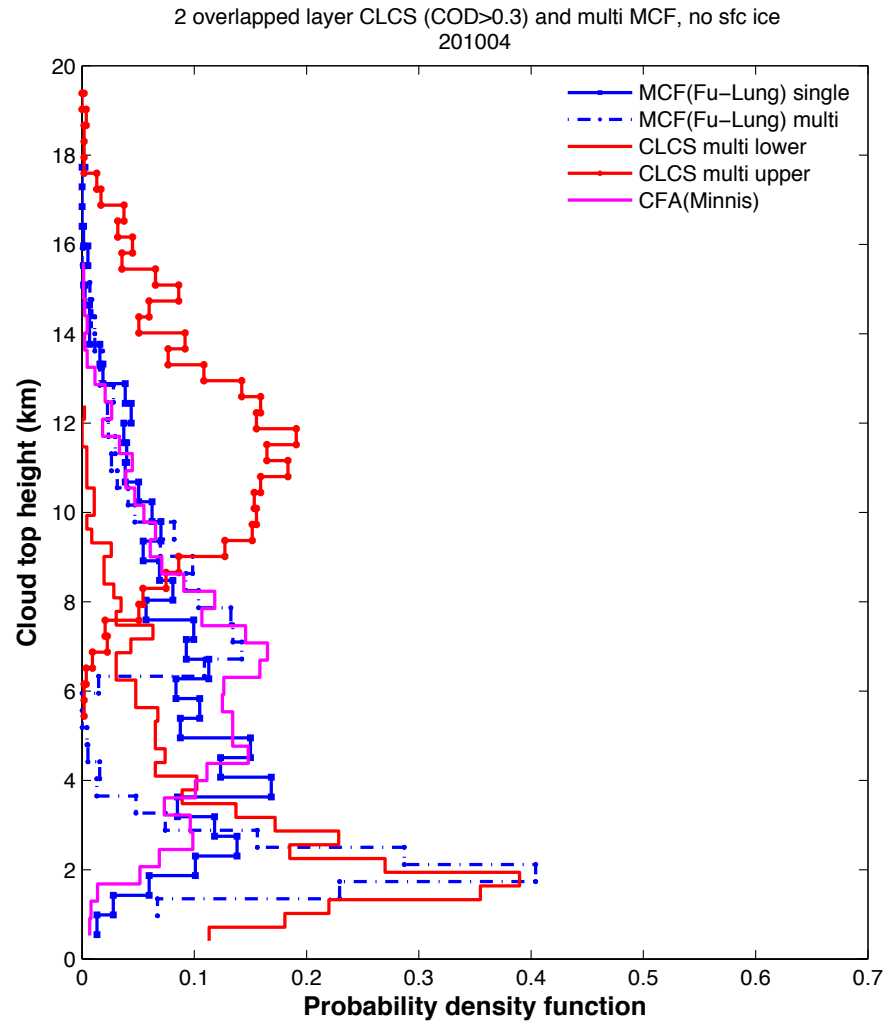
(201007) : MCF single (red) and multilayer (blue)
# of cases: 272 single, 1244 multi

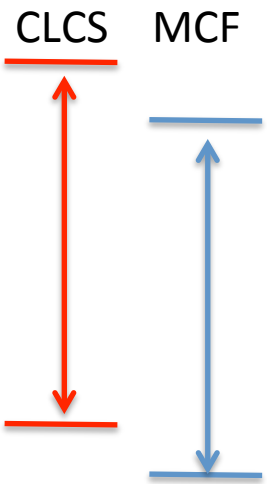


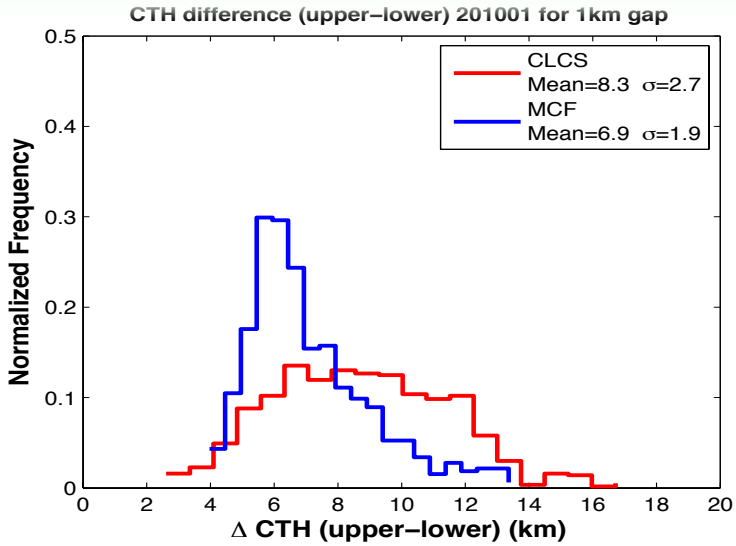
(201010) : MCF single (red) and multilayer (blue)
# of cases: 314 single, 1255 multi

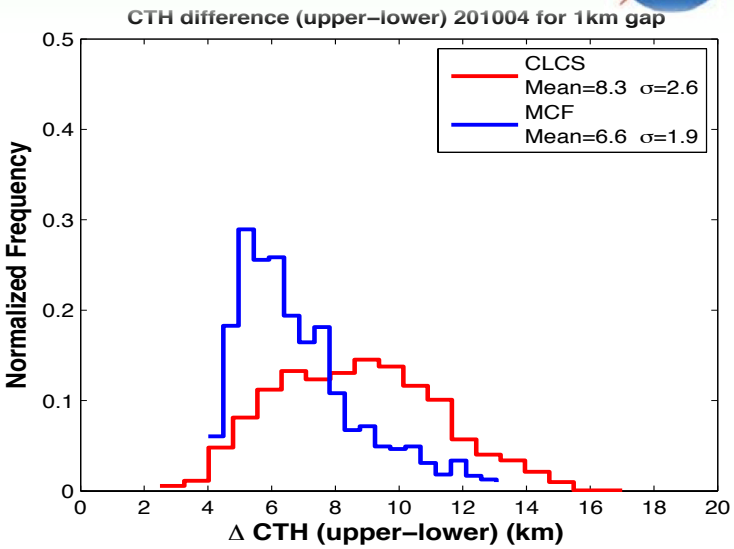


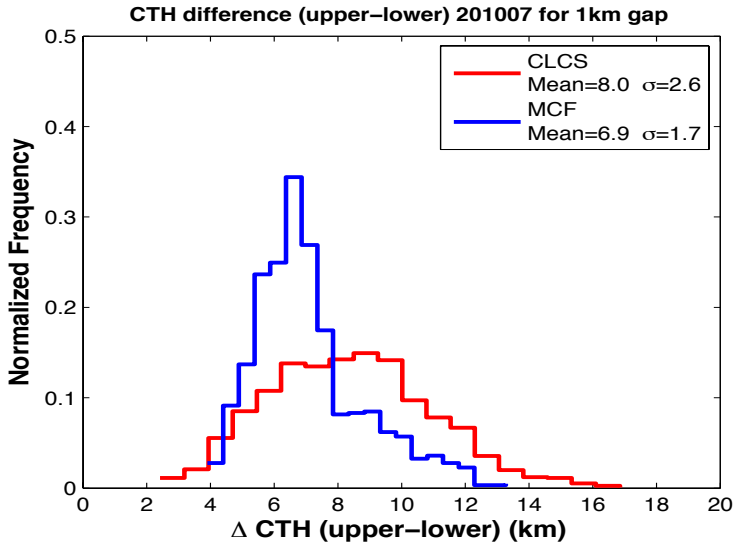

2 overlapped layer CLCS (COD>0.3) and single MCF, no sfc ice
201004
MCF(Fu−Lung) single
MCF(Fu−Lung) multi
CLCS multi lower
CLCS multi upper
CFA(Minnis)
Cloud top height (km)
Probability density function

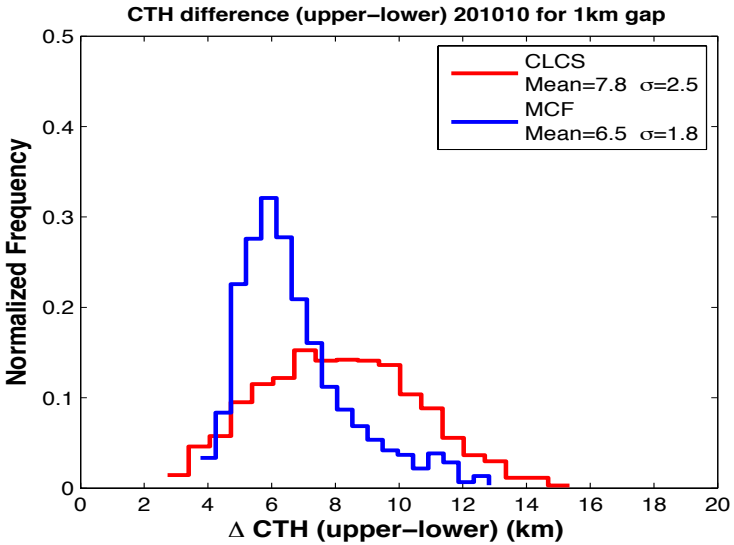

2 overlapped layer CLCS (COD>0.3) and multi MCF, no sfc ice
201004
MCF(Fu−Lung) single
MCF(Fu−Lung) multi
CLCS multi lower
CLCS multi upper
CFA(Minnis)
Cloud top height (km)
Probability density function

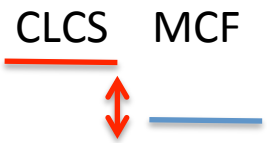

CLCS
MCF

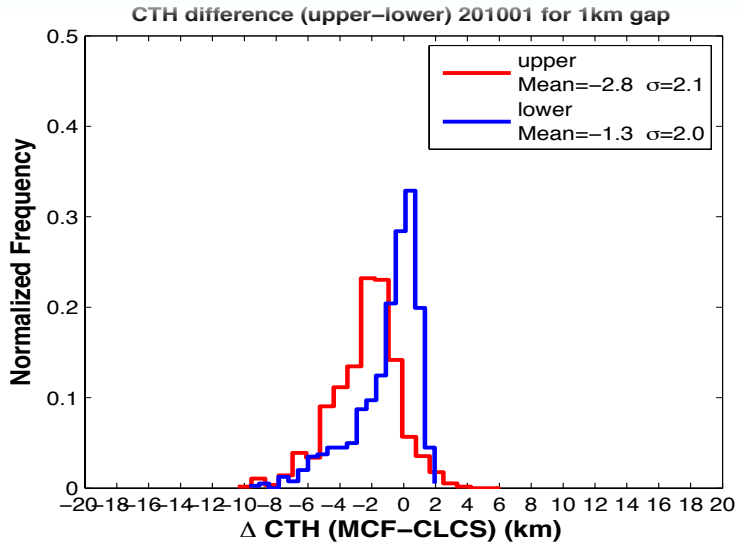

CTH difference (upper−lower) 201001 for 1km gap
CLCS
Mean=8.3 σ=2.7
MCF
Mean=6.9 σ=1.9
Normalized Frequency
Δ CTH (upper−lower) (km)

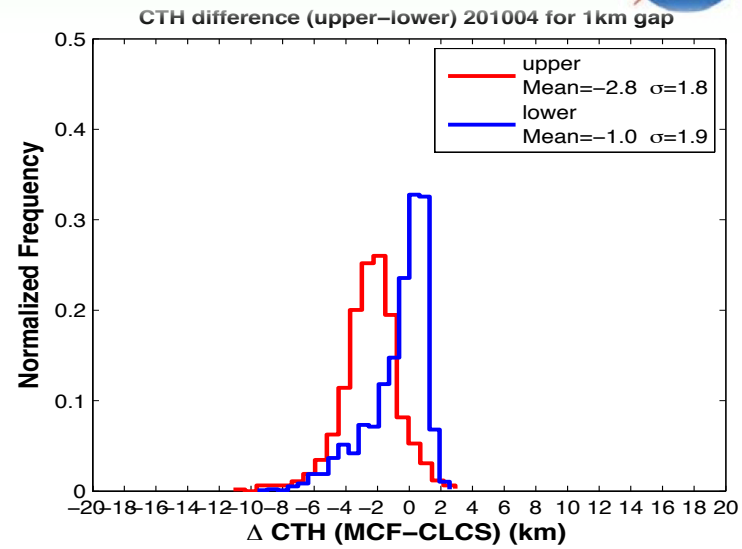

CTH difference (upper−lower) 201004 for 1km gap
CLCS
Mean=8.3 σ=2.6
MCF
Mean=6.6 σ=1.9
Normalized Frequency
Δ CTH (upper−lower) (km)

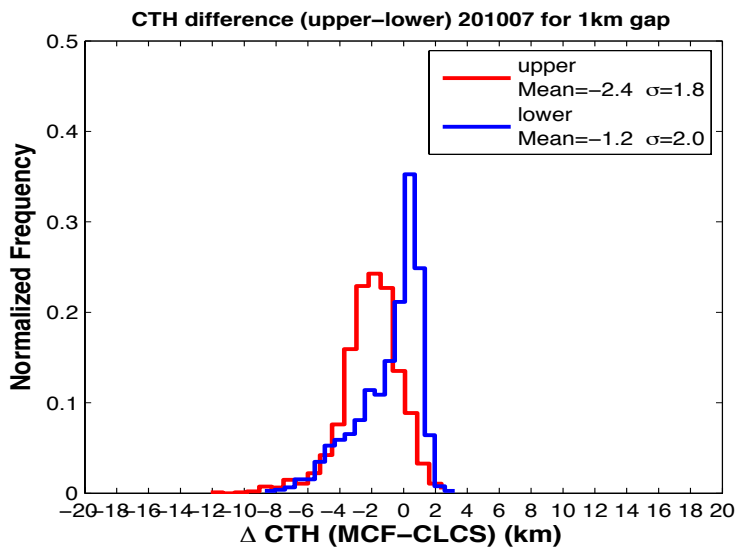

CTH difference (upper−lower) 201007 for 1km gap
CLCS
Mean=8.0 σ=2.6
MCF
Mean=6.9 σ=1.7
Normalized Frequency
Δ CTH (upper−lower) (km)

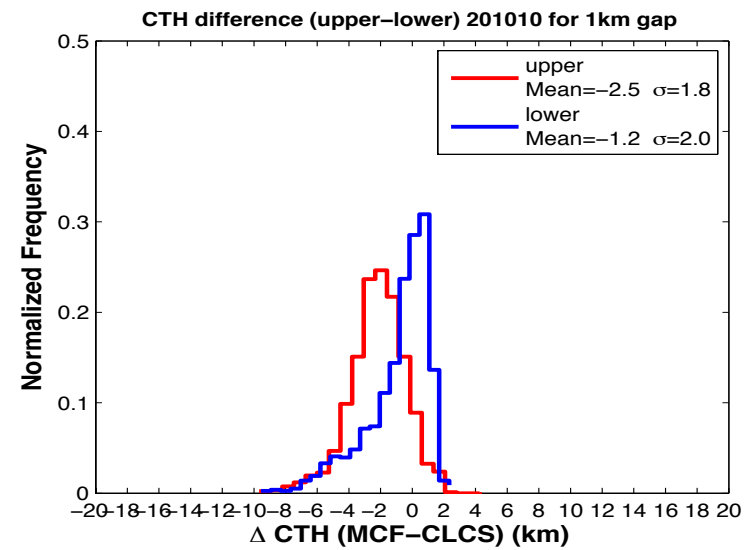

CTH difference (upper−lower) 201010 for 1km gap
CLCS
Mean=7.8 σ=2.5
MCF
Mean=6.5 σ=1.8
Normalized Frequency
Δ CTH (upper−lower) (km)


CLCS
MCF


CTH difference (upper−lower) 201001 for 1km gap
upper
Mean=−2.8 σ=2.1
lower
Mean=−1.3 σ=2.0
Normalized Frequency
Δ CTH (MCF−CLCS) (km)


CTH difference (upper−lower) 201004 for 1km gap
upper
Mean=−2.8 σ=1.8
lower
Mean=−1.0 σ=1.9
Normalized Frequency
Δ CTH (MCF−CLCS) (km)

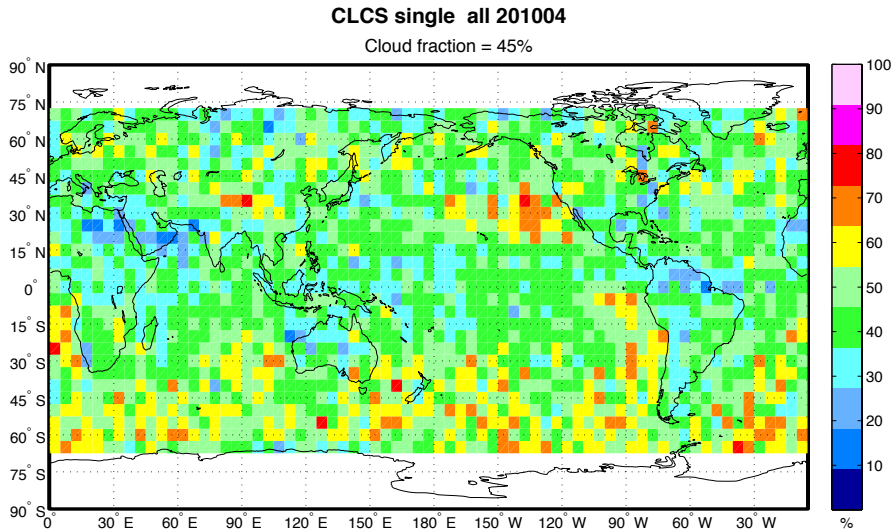

CTH difference (upper−lower) 201007 for 1km gap
upper
Mean=−2.4 σ=1.8
lower
Mean=−1.2 σ=2.0
Normalized Frequency
Δ CTH (MCF−CLCS) (km)

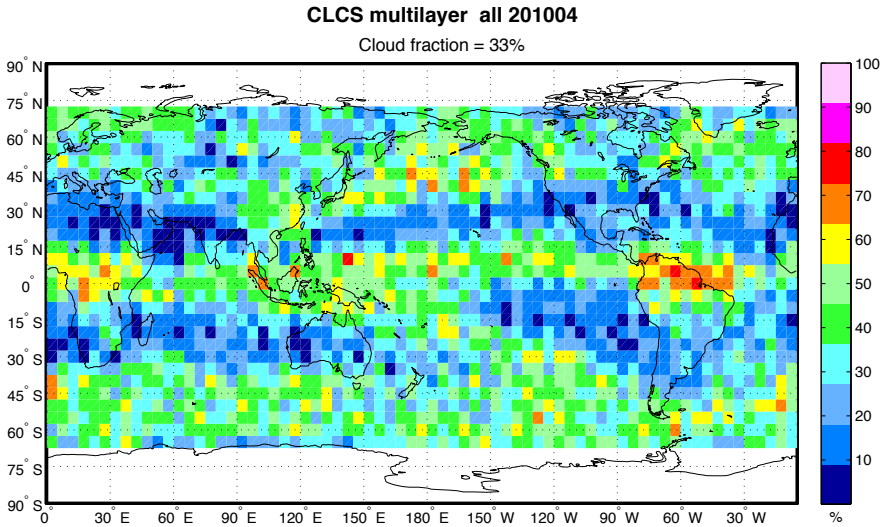

CTH difference (upper−lower) 201010 for 1km gap
upper
Mean=−2.5 σ=1.8
lower
Mean=−1.2 σ=2.0
Normalized Frequency
Δ CTH (MCF−CLCS) (km)

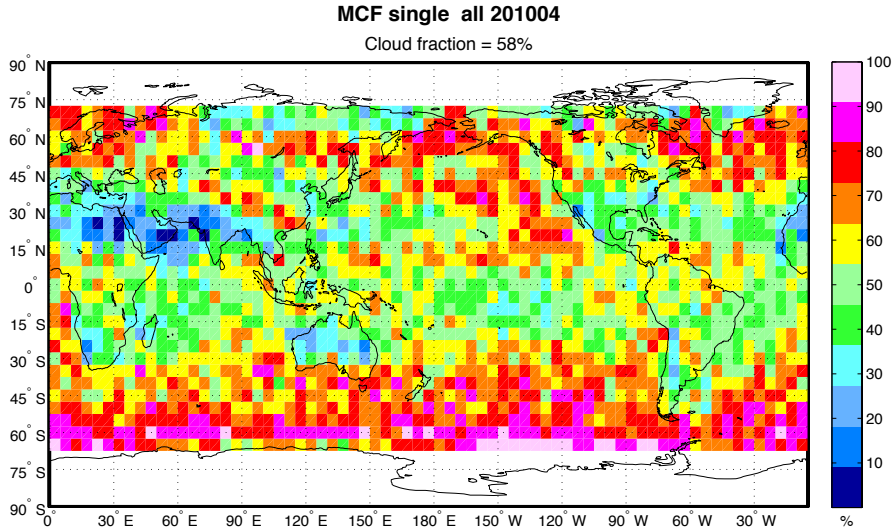
Conclusions and future work

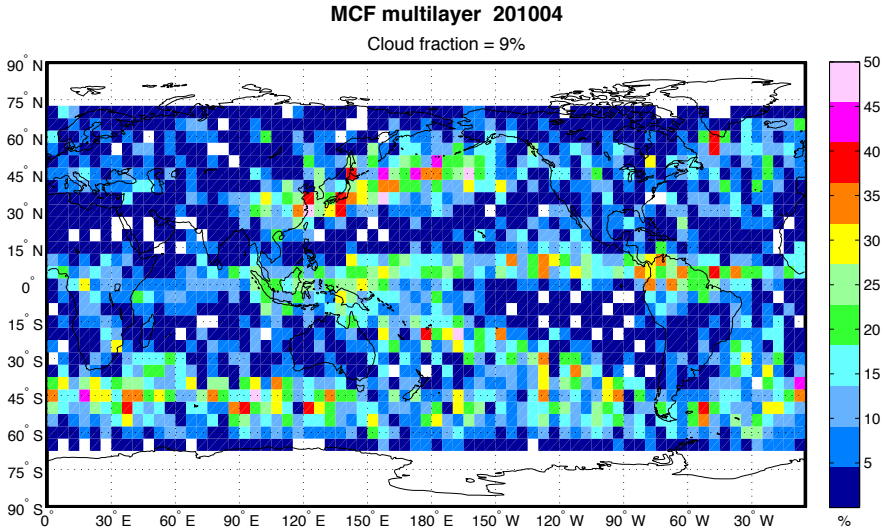
- The MCF algorithm (CERES-SSF Edition 4) has been evaluated to the CLCS cloud mask (CCCM Rel C1) for two particular cases:
  - For a CLCS single layer, MCF algorithm overestimates the presence of multilayer clouds in about ~**53%**. MCF overestimates ML clouds over thick high clouds.
  - For a CLCS 2 multilayered clouds (UL: CTP<600hPa and τ>0.3) in a CERES footprint, MCF agrees very well to CLCS, in about ~**83%**.
  - Nevertheless for 2 multilayer case, MCF underestimates the upper layer height (CTH upper) in about 2.6±0.4 km and the lower layer height (CTH lower)in about 1.2±0.5 km.
  - For both cases evaluated (single and Multi), MCF does not show a clear pattern where disagrees to CLCS.
- Evaluate the multilayer cloud climatology since there are records of CLCS and the CERES SSF-Edition 4 cloud multilayer footprint product.

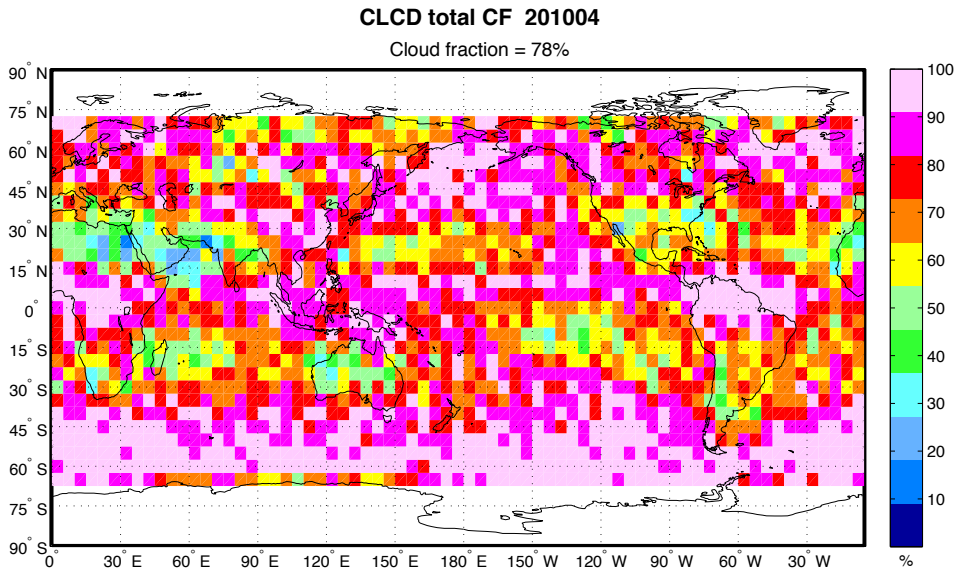

Thanks for your attention

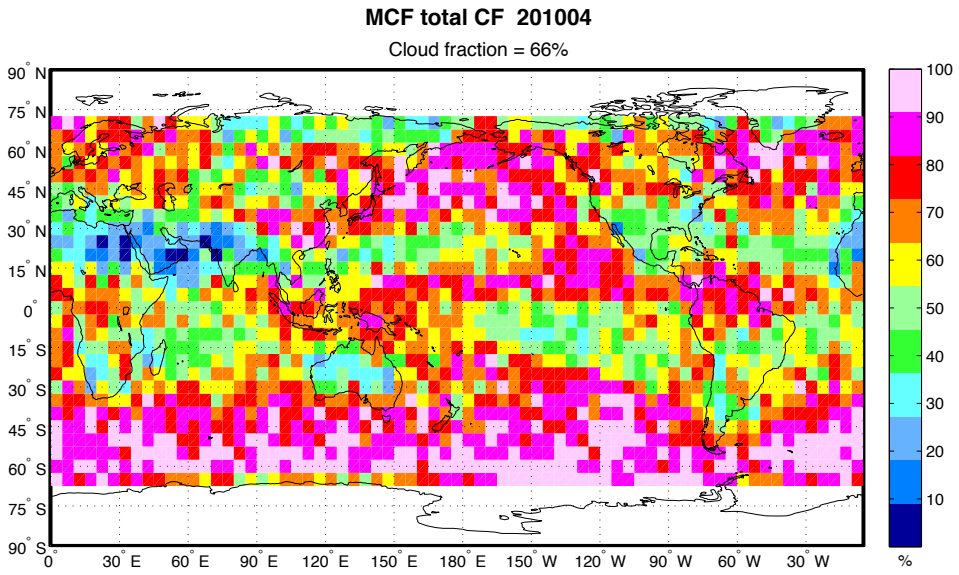

CLCS single all 201004
Cloud fraction = 45%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%

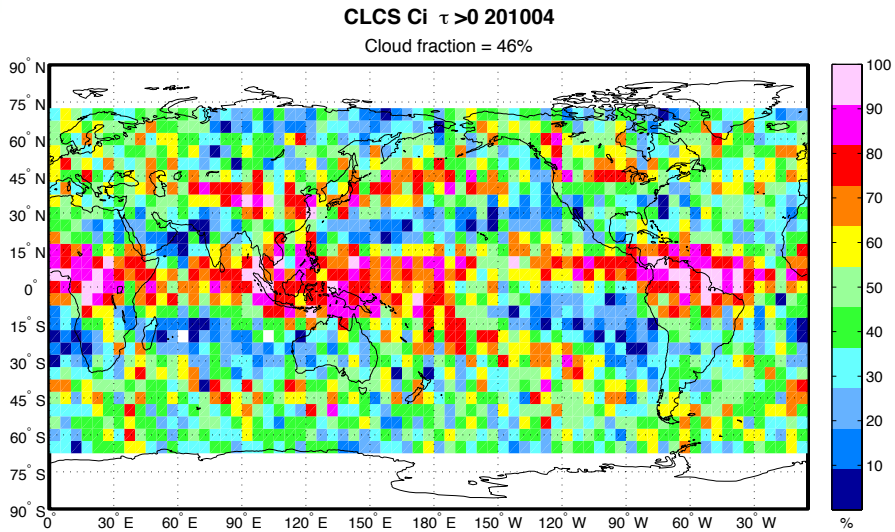

CLCS multilayer all 201004
Cloud fraction = 33%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%

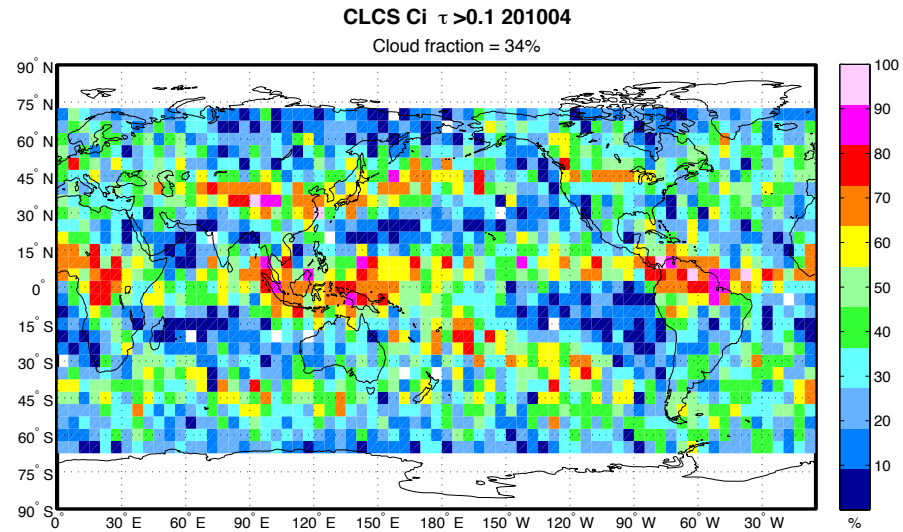

MCF single all 201004
Cloud fraction = 58%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%

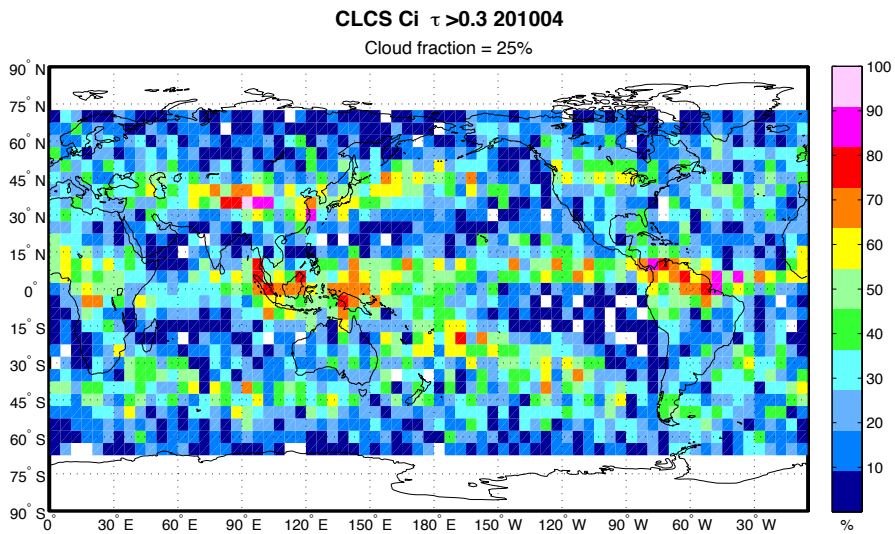

MCF multilayer 201004
Cloud fraction = 9%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
50
45
40
35
30
25
20
15
10
5
%

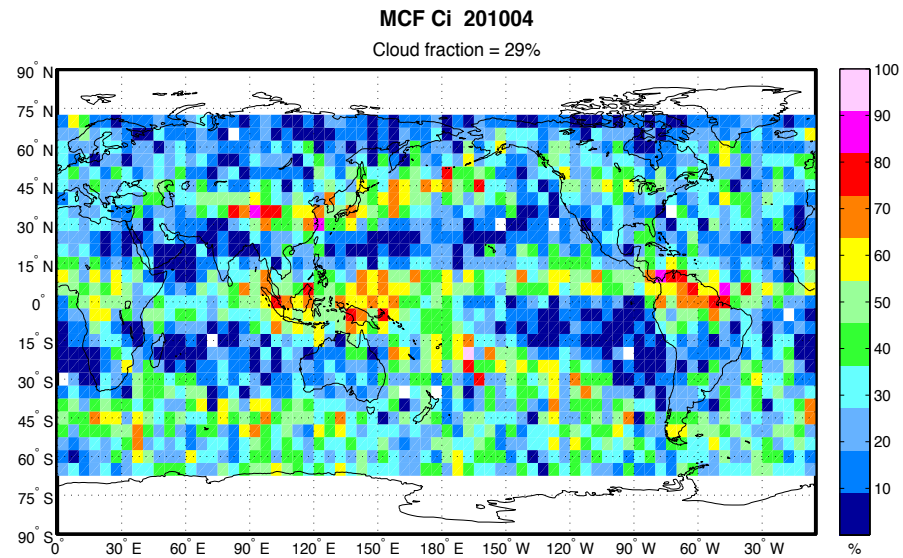

CLCD total CF 201004
Cloud fraction = 78%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0°
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%

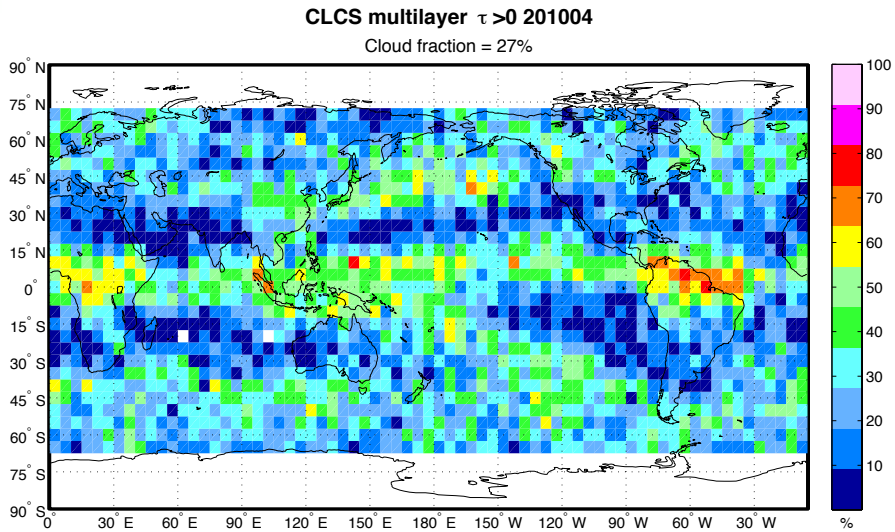

MCF total CF 201004
Cloud fraction = 66%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0°
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%

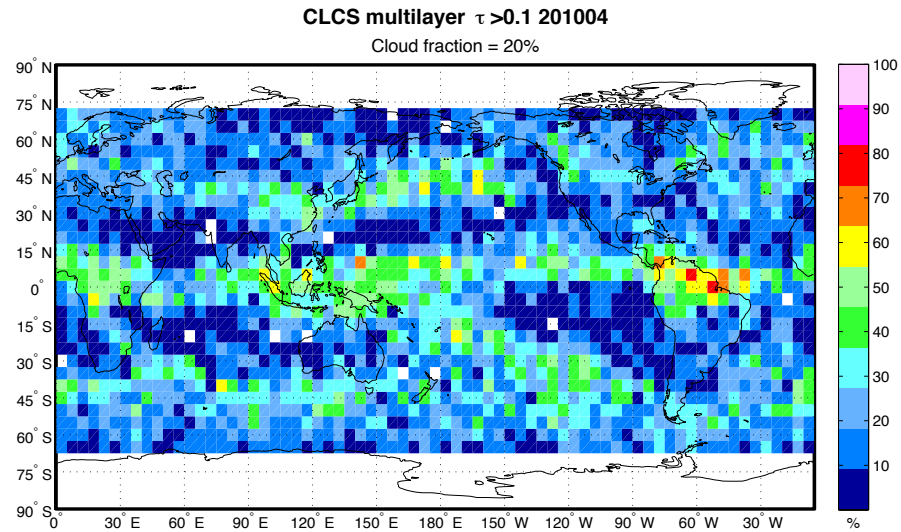

CLCS Ci τ >0 201004
Cloud fraction = 46%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%

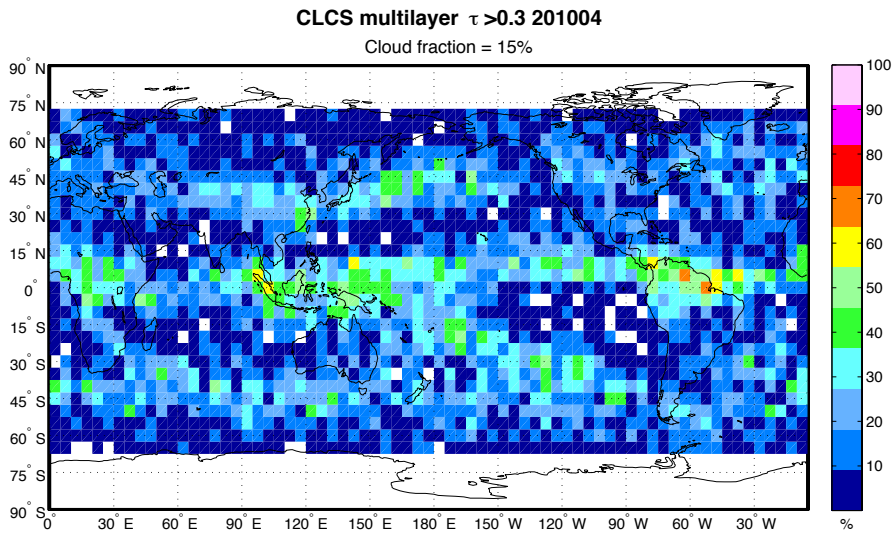

CLCS Ci τ >0.1 201004
Cloud fraction = 34%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%

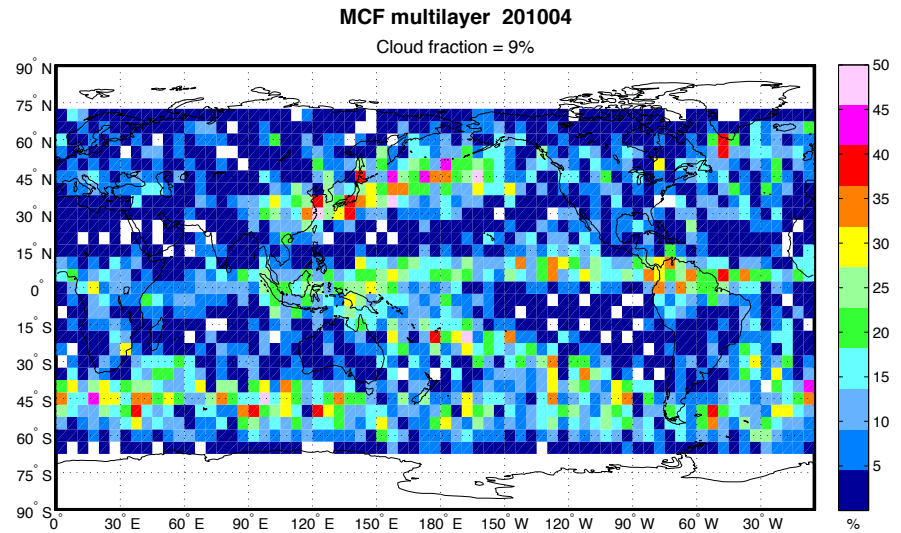

CLCS Ci τ >0.3 201004
Cloud fraction = 25%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%


MCF Ci 201004
Cloud fraction = 29%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%


CLCS multilayer τ >0 201004
Cloud fraction = 27%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%


CLCS multilayer τ >0.1 201004
Cloud fraction = 20%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%


CLCS multilayer τ >0.3 201004
Cloud fraction = 15%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
100
90
80
70
60
50
40
30
20
10
%


MCF multilayer 201004
Cloud fraction = 9%
90° N
75° N
60° N
45° N
30° N
15° N
0°
15° S
30° S
45° S
60° S
75° S
90° S
0
30° E
60° E
90° E
120° E
150° E
180° E
150° W
120° W
90° W
60° W
30° W
50
45
40
35
30
25
20
15
10
5
%

CALIPSO-CloudSat case #1 (SINGLE)
Attenuated signal top height profiles

	CLCS	MCF			
CALIOP att	**single**	**single**	**overlap**	**both**	
footprints	1862	628	329	905	**January**
%	**100**	**33.7**	**17.7**	**48.6**	
footprints	4396	1736	450	2210	**April**
%	**100**	**39.5**	**10.2**	**50.3**	
footprints	3691	1385	389	1917	**July**
%	**100**	**37.5**	**10.5**	**51.9**	
footprints	4149	1458	542	2149	**October**
%	**100**	**35.1**	**13.1**	**51.8**	

MCF		
single	**overlap**	**both**
36.5	12.9	50.7

- CLCS single group with attenuated signal : attenuation for CTP<600hPa

CALIPSO-CloudSat case #1 (SINGLE)
Attenuated signal top height profiles