Cloud Cover Validation using Surface Instruments

R. Welch[1], T. Berendes[1], D. Berendes[1],
E. Dutton[2], T. Uttal[3], P. Minnett[4] , E. Clothiaux[5]

[1] Dept. of Atmospheric Sciences, Univ. of Alabama in Huntsville
[2] NOAA/Climate Monitoring and Diagnostics Laboratory
[3] NOAA/Environmental Technology Laboratory
[4] Rosenstiel School of Marine and Atmospheric Science, Univ. of Miami
[5] Dept. of Meteorology, Pennsylvania State University

Cloud Mask Evaluation

- Visual using IVICS - subjective
  - Quick feedback for training process
  - Analyst interpretation may be biased
- NNW accuracy
  - Independent samples
  - Hard numbers
  - Analyst may be unable to discern cirrus and sub-resolution cumulus

Cloud Mask Evaluation cont.

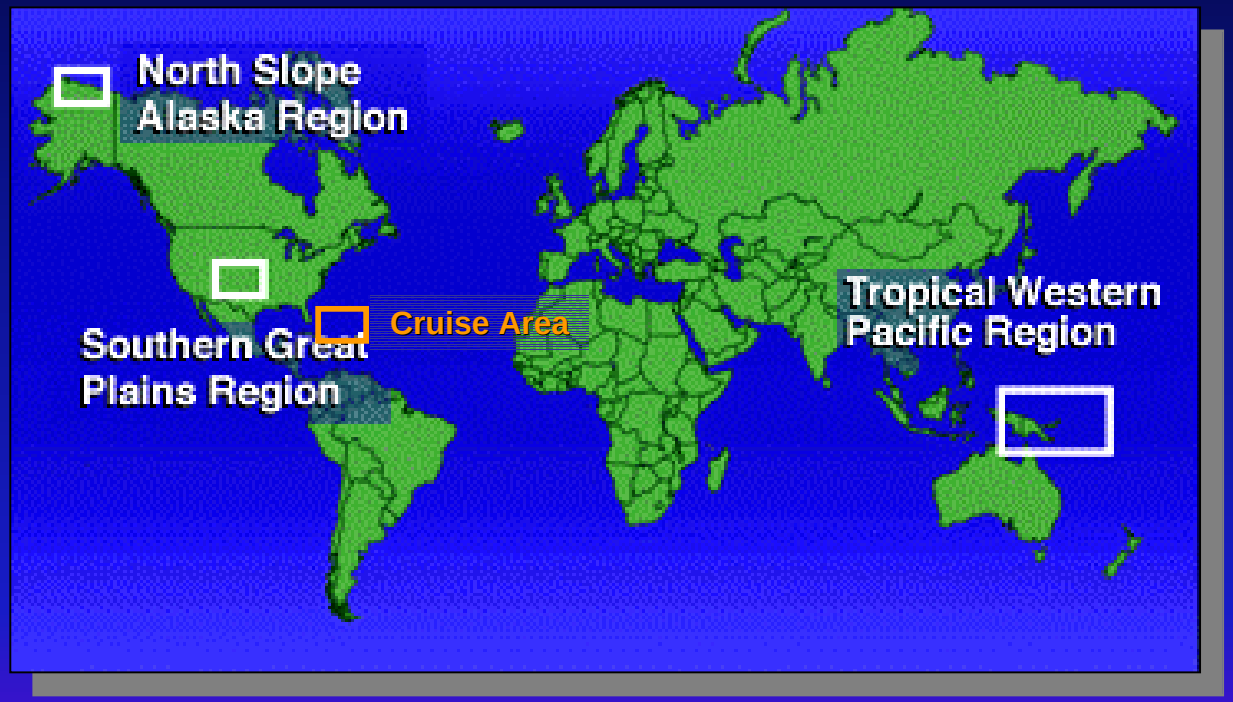
- "Validation" using surface instruments
  - Data independent of satellite
  - Minimal analyst interpretation
  - Multiple instruments and sites
  - Applicable to any cloud masking algorithm
  - Expandable database
  - Batch mode processing
  - Integrated with IVICS - user friendly

Neural Network Classification Accuracy

	Accuracy (%)	
Region	**Overall**	**Cloud Only**
Polar	96	97
Sunglint	92	99
Global	94	96

Surface Validation Sites

- Atmospheric Radiation Measurement Program (ARM)



- Explorer of the Seas cruise ship - S.E. Atlantic, Caribbean Sea

ARM Cloud Instruments

Vaisala Ceilometer (VCEIL)

Millimeter Wavelength Cloud Radar (MMCR)

Micropulse Lidar (MPL)

Whole Sky Imager (WSI)

- Southern Great Plains (SGP)
  - Aug 2000 – Jun 2002 VCEIL, MPL, WSI
- North Slope of Alaska (NSA)
  - Aug 2000 – Jun 2002 VCEIL, MPL, WSI
  - Jan – Dec 2000 MMCR (Uttal processed)

Cruise Ship Instruments

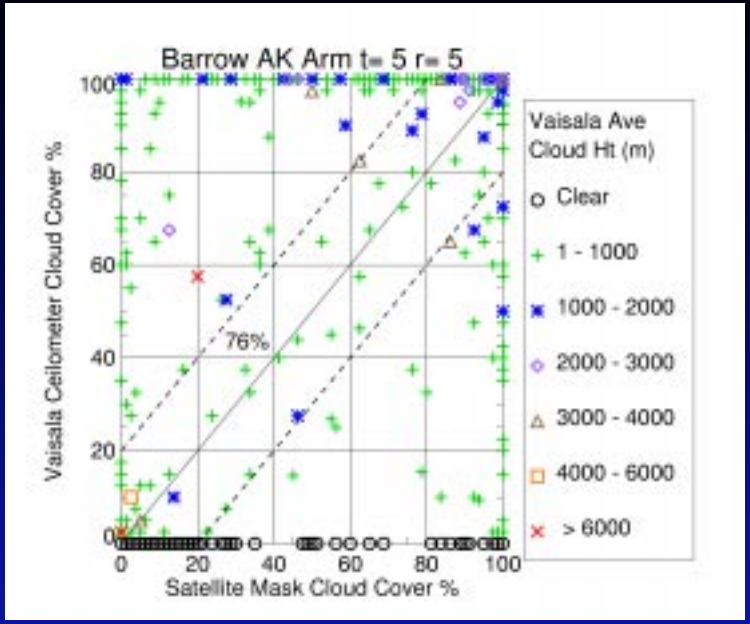
- Vaisala Ceilometer, Total Sky Imager (Jan – June 2001)

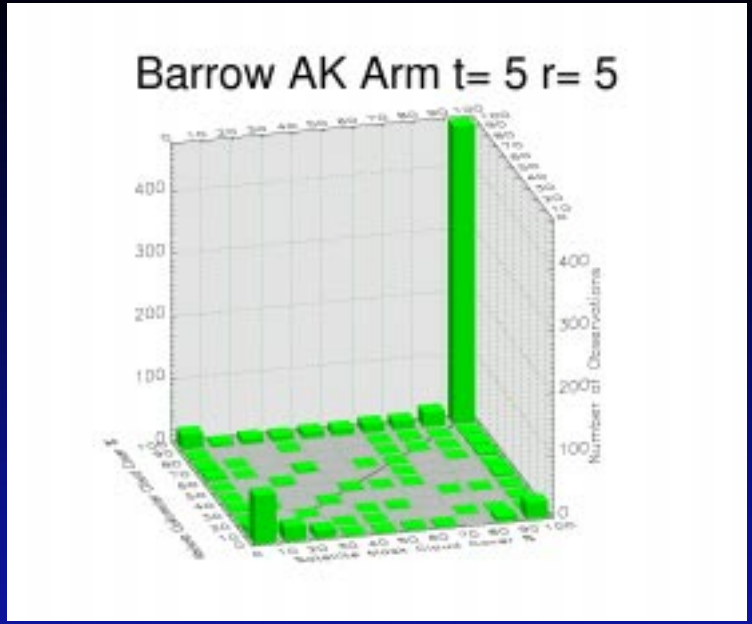
Surface Instrument Data

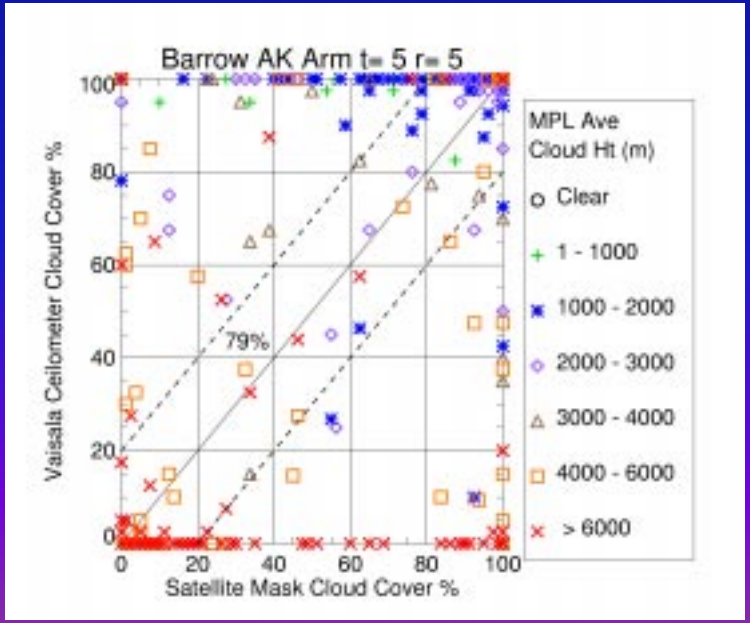
- Cloud Cover
  - Vaisala Ceilometer (VCEIL)
  - Micropulse Lidar (MPL)
  - Millimeter Wavelength Cloud Radar (MMCR)
  - Active Remote Sensing of Clouds (ARSCL)
  - Whole / Total sky imager (WSI / TSI)
- Estimated optical depth (EOD) - Normal Incidence Pyrheliometer (NIP)
- Cloud height - VCEIL, MPL, ARSCL

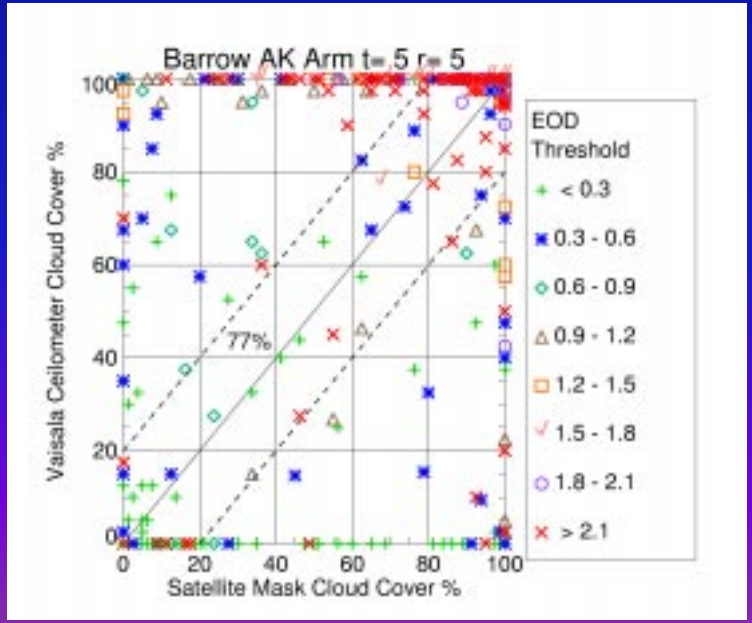
Validation of Cloud Mask

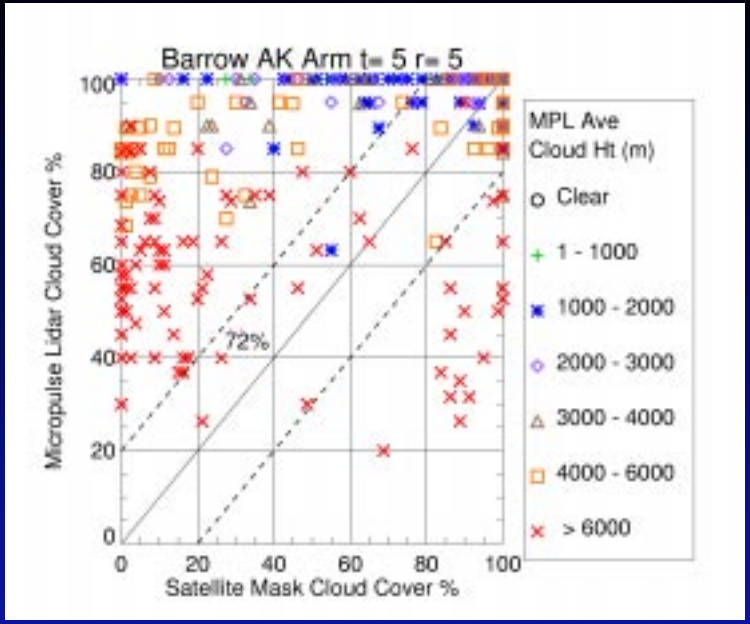
- MODIS data over surface sites
  - Over 2000 images Aug 2000 – May 2002
  - Extract pixels for 5, 10, 15 km site radii
  - Classify pixels and create cloud mask
  - Compute cloud cover (spatial)
- Surface cloud cover instrument data
  - Match overpass time +/- 5, 10, 15, and 20 min
  - Compute cloud cover over time interval (WSI and TSI computed spatially at overpass time)
- Intercompare and analyze using height and EOD data (NIP)

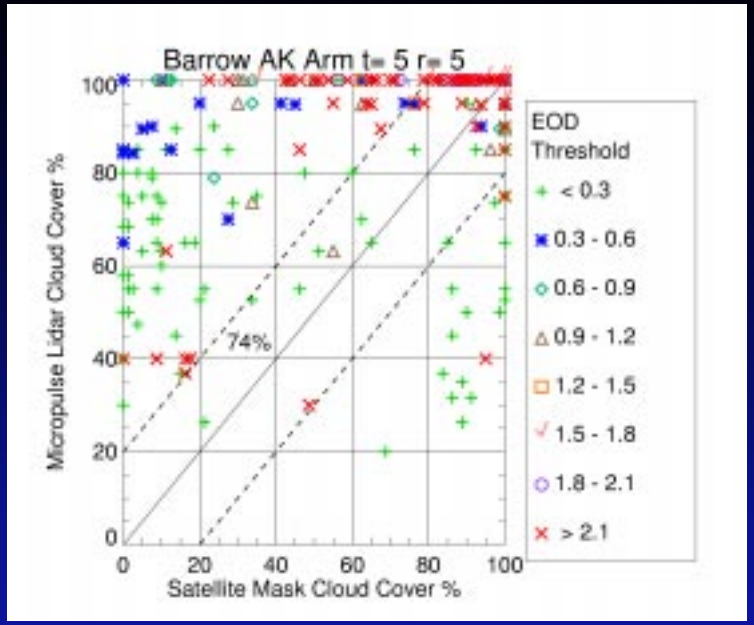

Barrow AK Arm t= 5 r= 5
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
76%
Vaisala Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

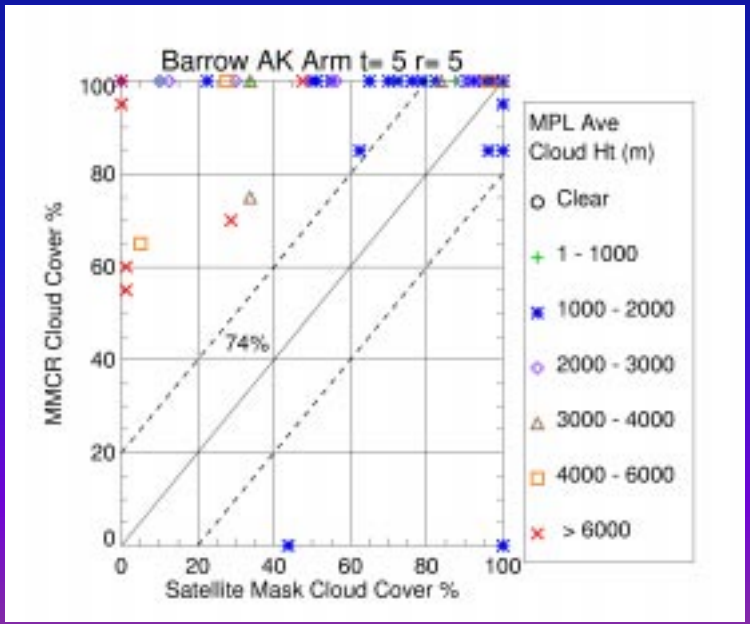

Barrow AK Arm t= 5 r= 5
Number of Observations

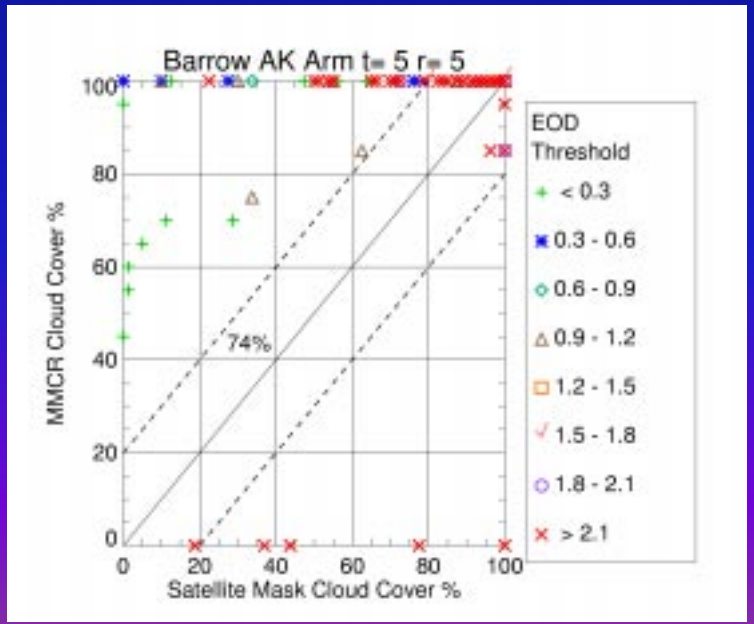

Barrow AK Arm t= 5 r= 5
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
79%
MPL Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

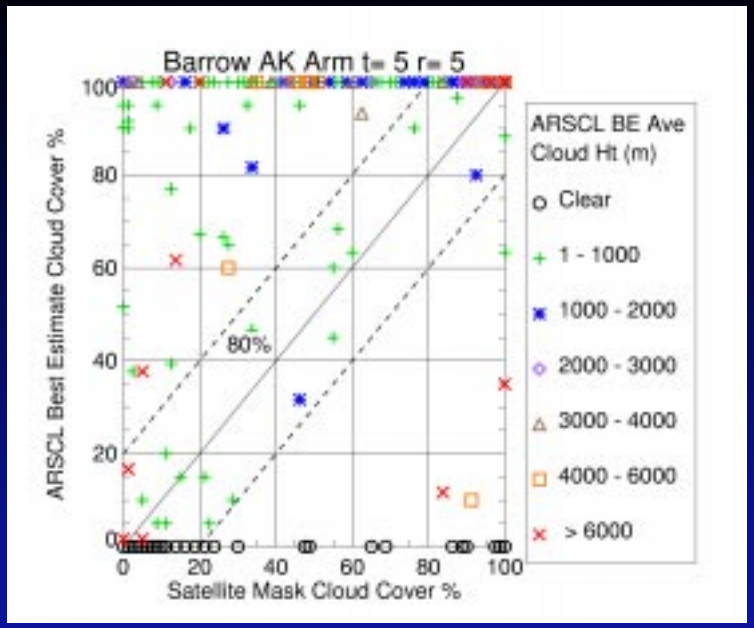

Barrow AK Arm t= 5 r= 5
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
77%
EOD Threshold
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1

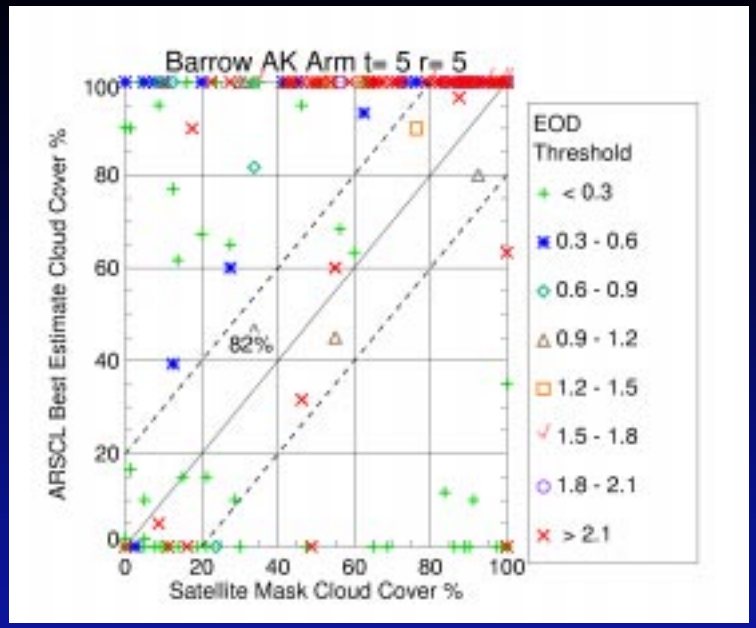

Barrow AK Arm t= 5 r= 5
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
72%
MPL Ave
Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

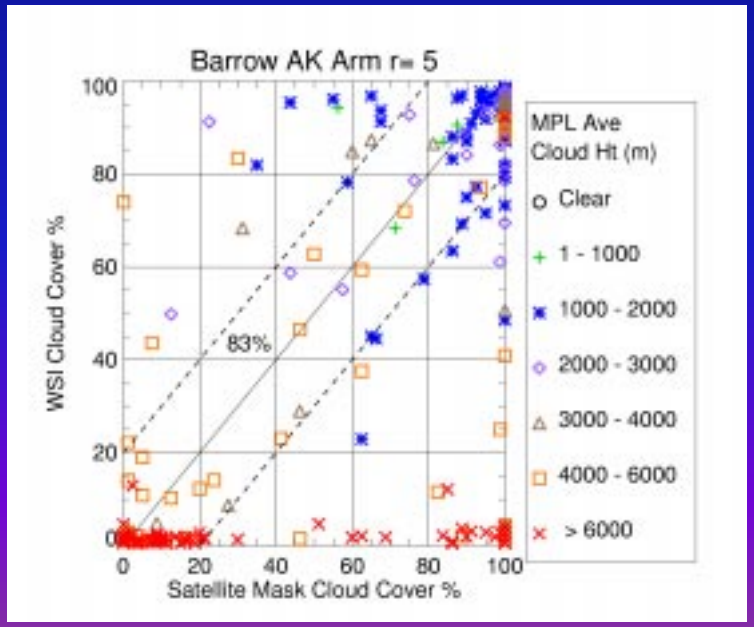

Barrow AK Arm t= 5 r= 5
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
74%
EOD
Threshold
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1

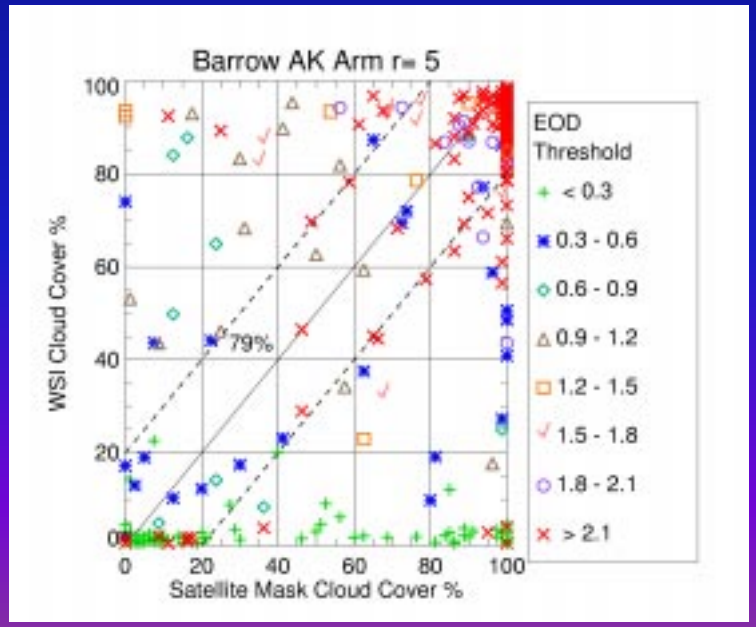

Barrow AK Arm t= 5 r= 5
MMCR Cloud Cover %
Satellite Mask Cloud Cover %
74%
MPL Ave
Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

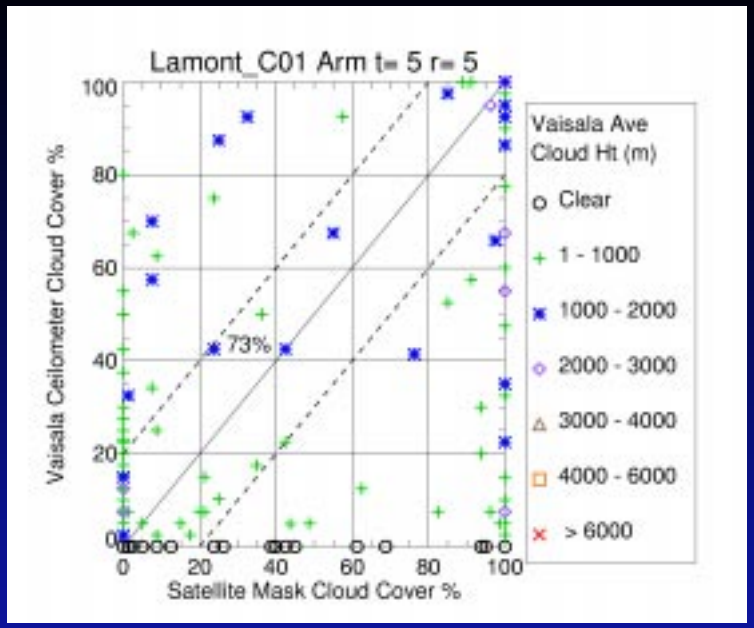

Barrow AK Arm t= 5 r= 5
MMCR Cloud Cover %
Satellite Mask Cloud Cover %
74%
EOD
Threshold
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1

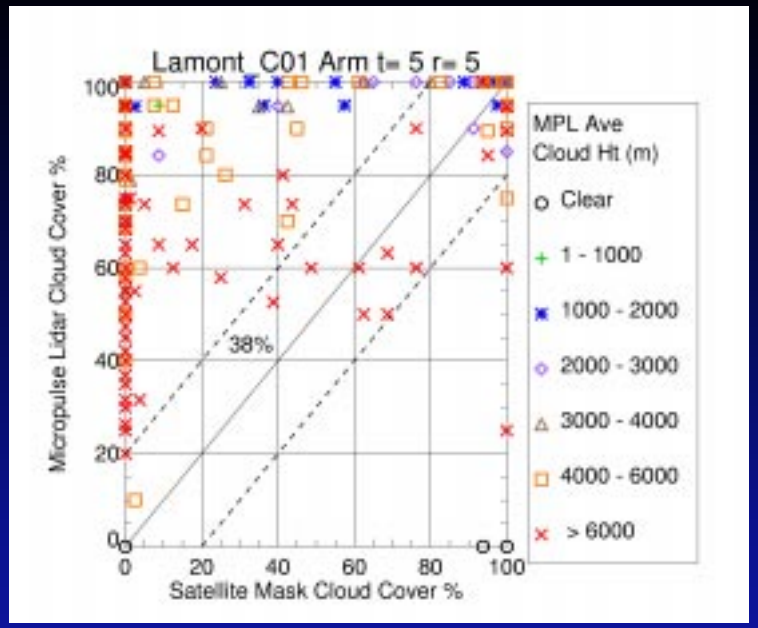

Barrow AK Arm t= 5 r= 5
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %
80%
ARSCL BE Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

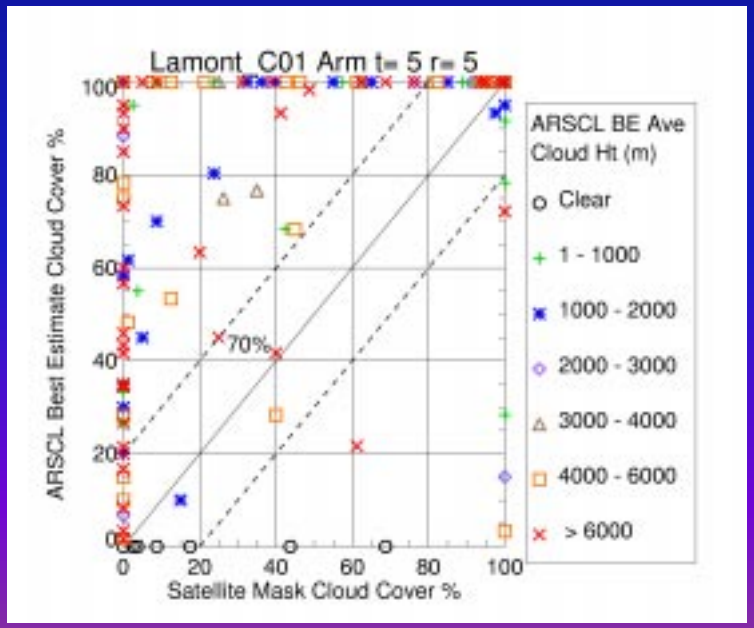

Barrow AK Arm t= 5 r= 5
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %
82%
EOD Threshold
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1

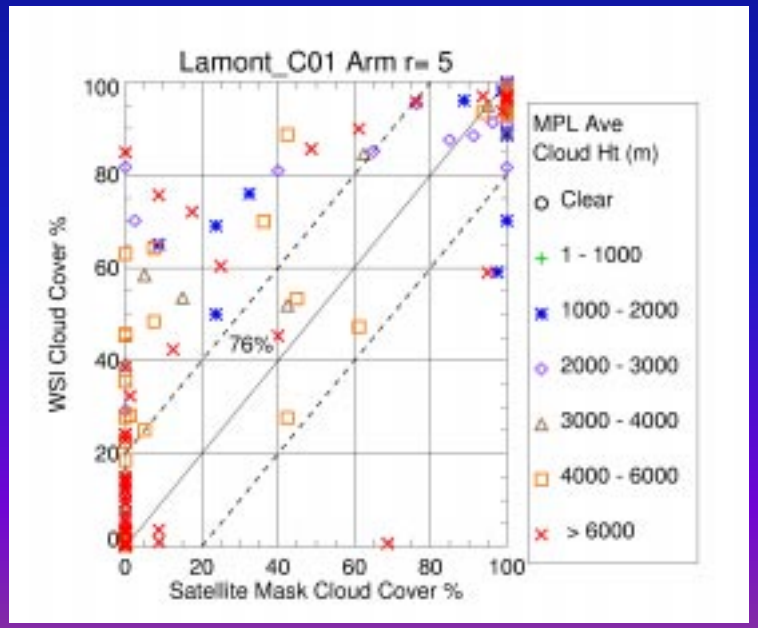

Barrow AK Arm r= 5
WSI Cloud Cover %
Satellite Mask Cloud Cover %
83%
MPL Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

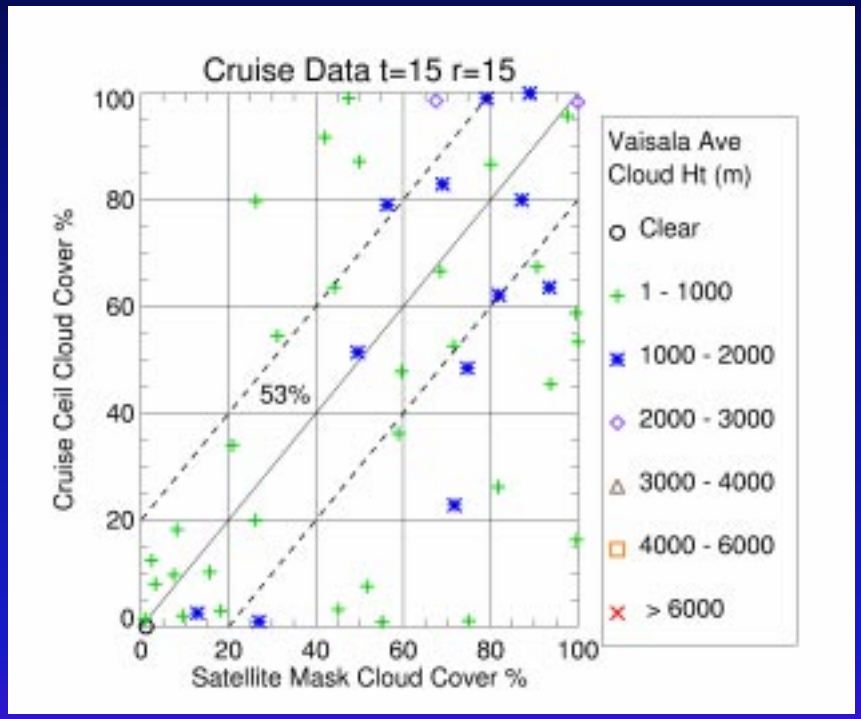

Barrow AK Arm r= 5
WSI Cloud Cover %
Satellite Mask Cloud Cover %
79%
EOD Threshold
< 0.3
0.3 - 0.6
0.6 - 0.9
0.9 - 1.2
1.2 - 1.5
1.5 - 1.8
1.8 - 2.1
> 2.1

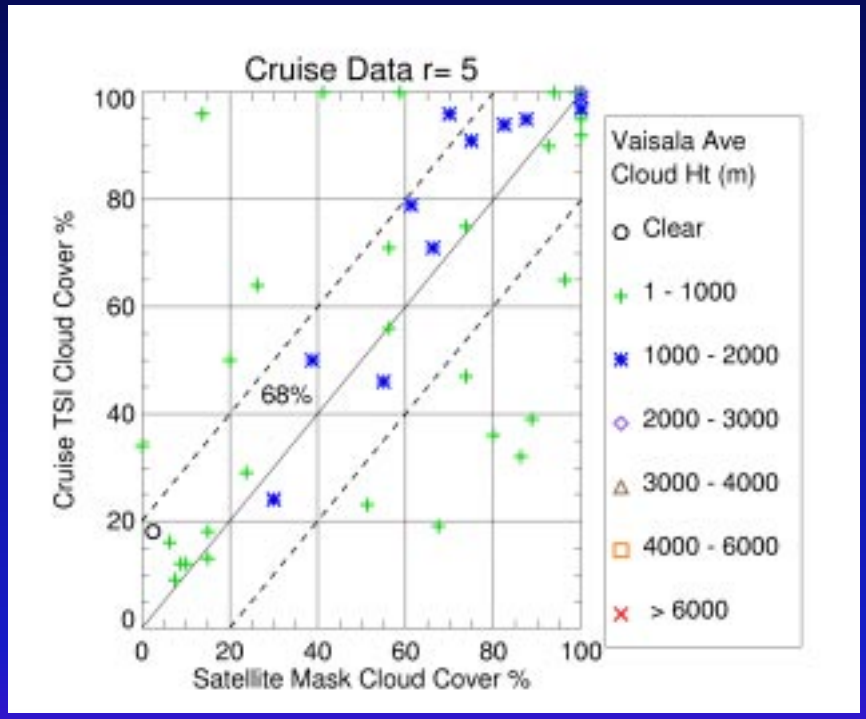

Lamont_C01 Arm t= 5 r= 5
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
73%
Vaisala Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

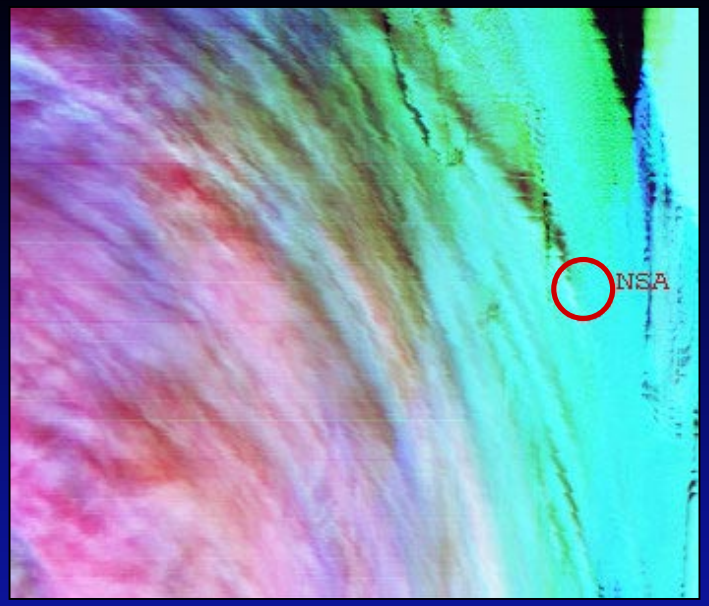

Lamont_C01 Arm t= 5 r= 5
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
38%
MPL Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

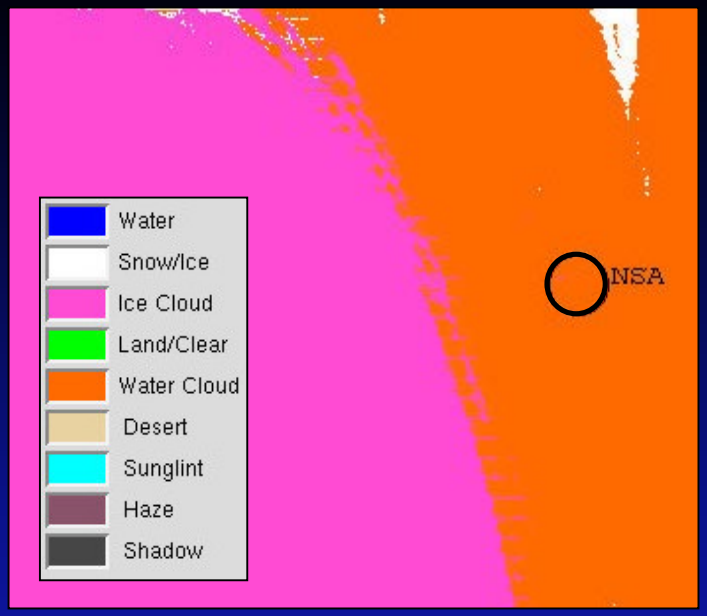

Lamont_C01 Arm t= 5 r= 5
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %
70%
ARSCL BE Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000


Lamont_C01 Arm r= 5
WSI Cloud Cover %
Satellite Mask Cloud Cover %
76%
MPL Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000


Cruise Data t=15 r=15
Cruise Ceil Cloud Cover %
Satellite Mask Cloud Cover %
53%
Vaisala Ave
Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000


Cruise Data r= 5
Cruise TSI Cloud Cover %
Satellite Mask Cloud Cover %
68%
Vaisala Ave
Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

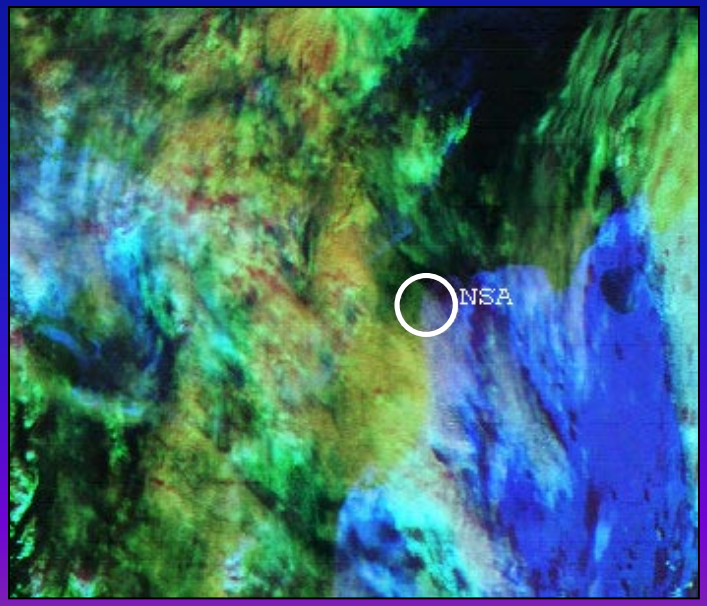


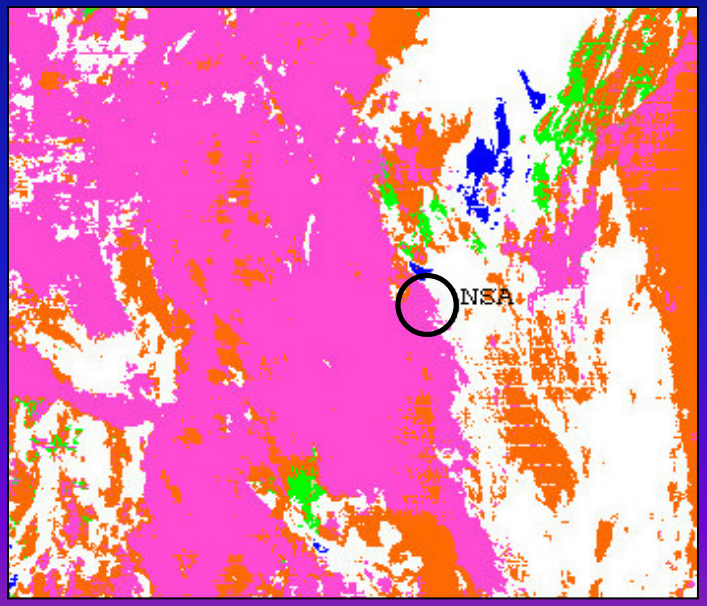


Sat Mask 100

VCEIL 100
MPL 100
MMCR 100
ARSCL 100

EOD >2.1

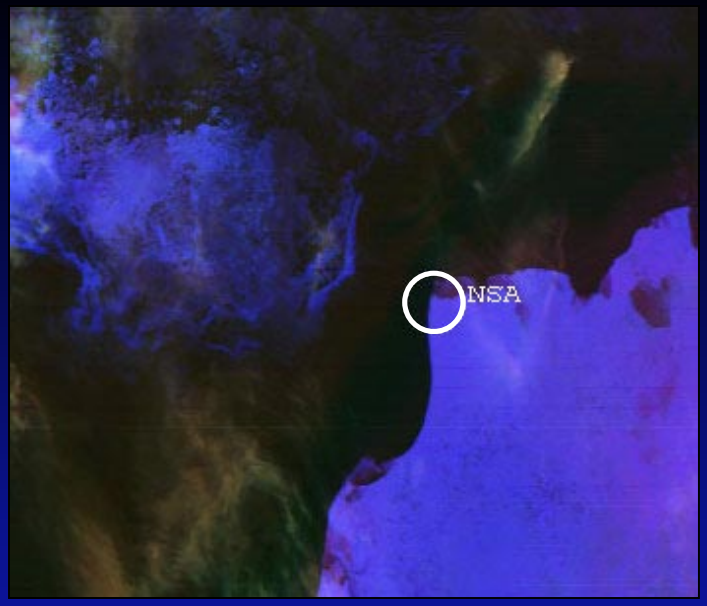




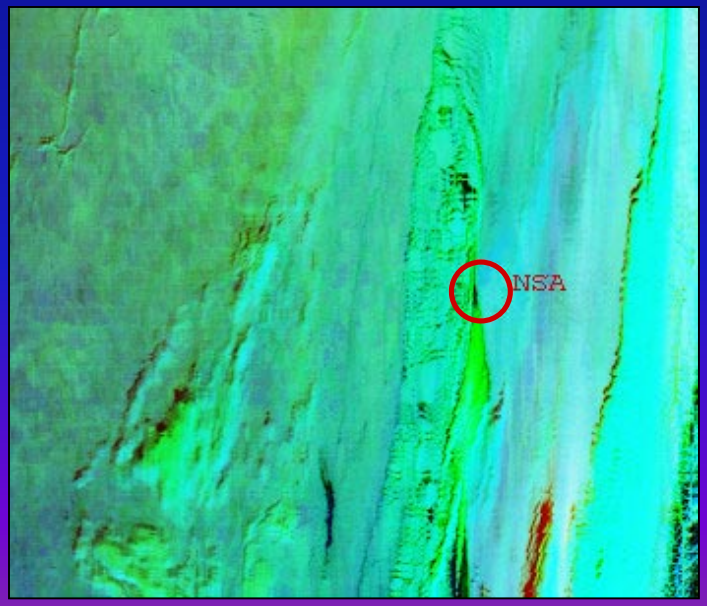
Sat Mask 52

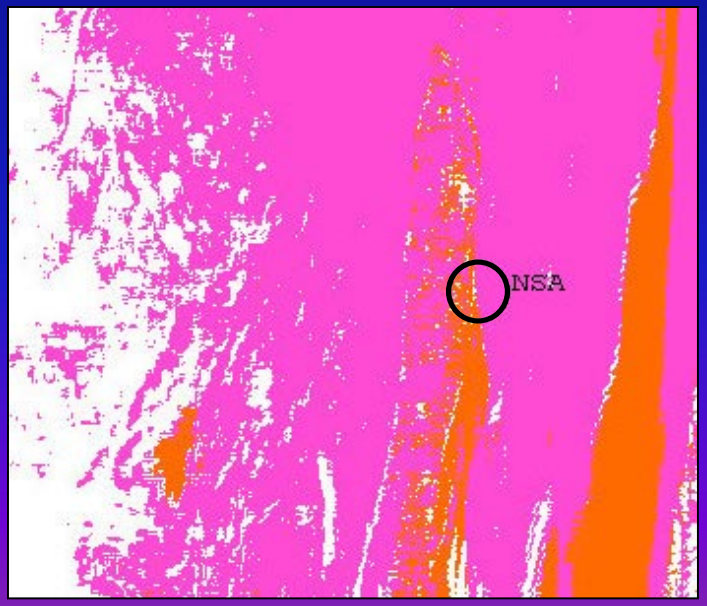
VCEIL 100
MPL 100
MMCR 100
ARSCL 100

EOD 1.2



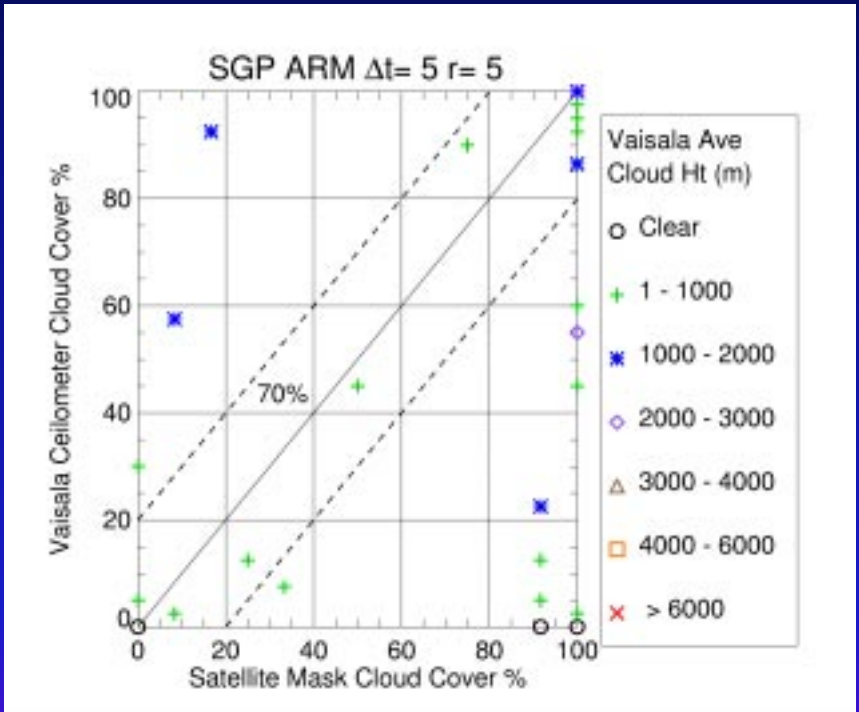
Sat Mask	0
VCEIL	0
MPL	71
WSI	1
MMCR	100
ARSCL	0
EOD	0.3



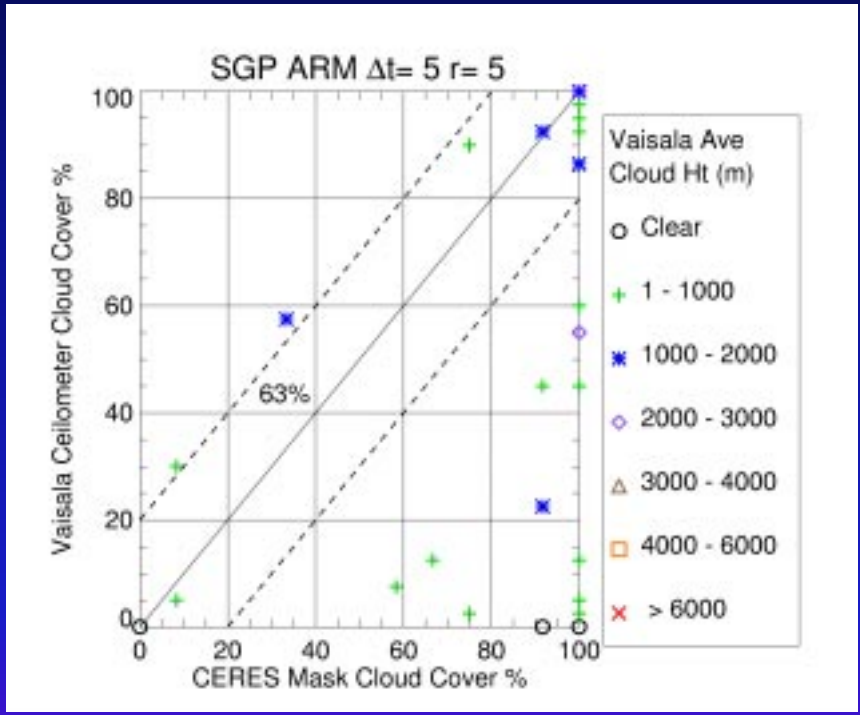


Sat Mask	100
VCEIL	0
MPL	50
WSI	3
ARSCL	0
EOD	0.3
SZ	70
VZ	55

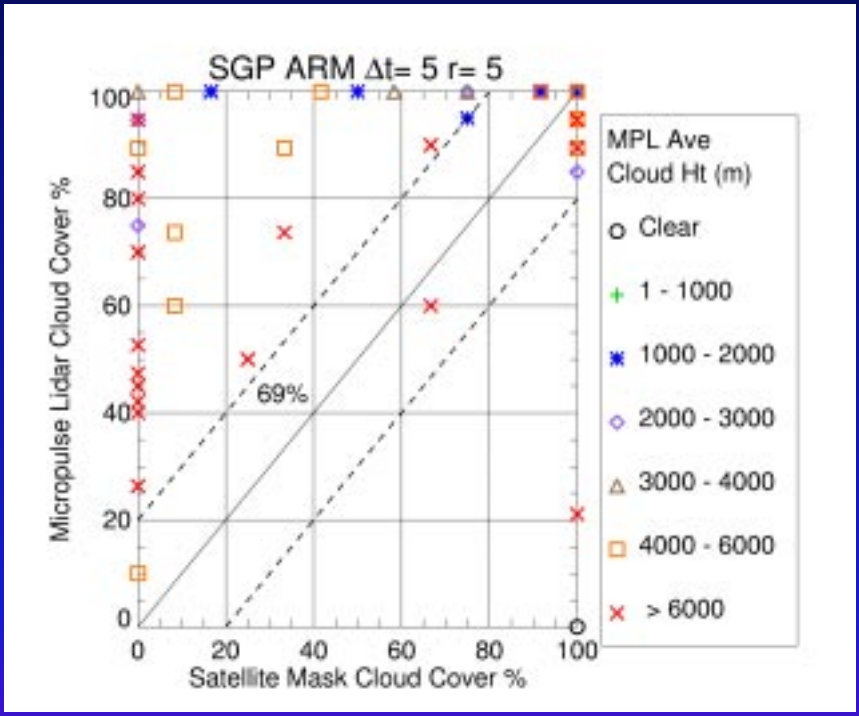
UAH


SGP ARM Δt= 5 r= 5
Vaisala Ceilometer Cloud Cover %
Satellite Mask Cloud Cover %
70%
Vaisala Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

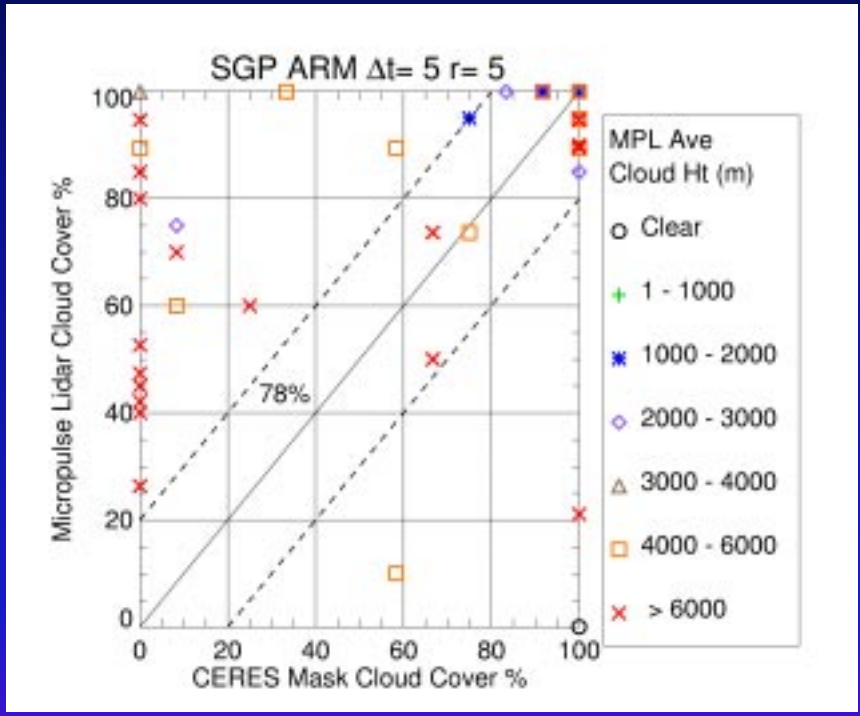
CERES


SGP ARM Δt= 5 r= 5
Vaisala Ceilometer Cloud Cover %
CERES Mask Cloud Cover %
63%
Vaisala Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

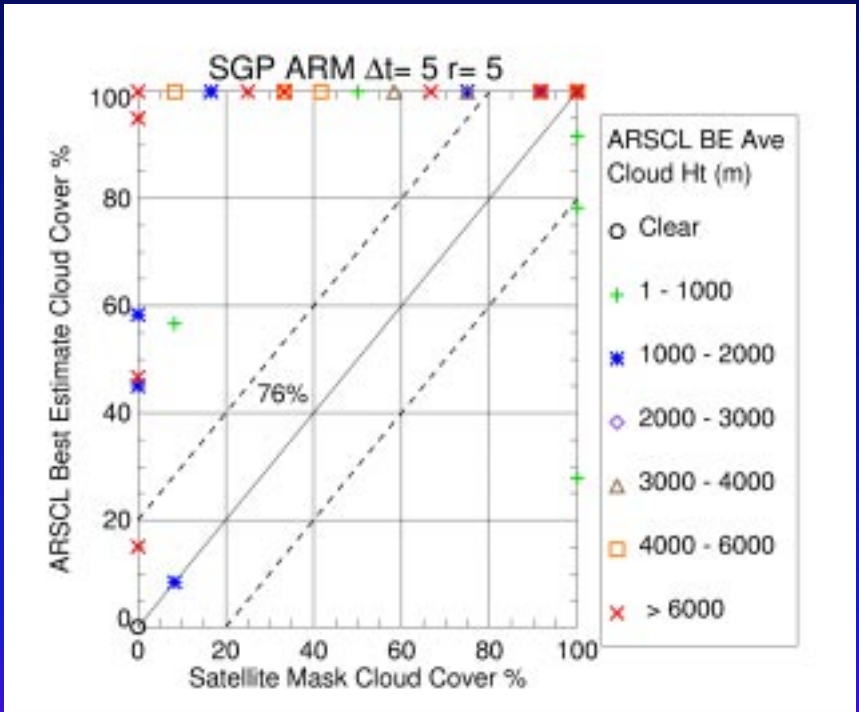
UAH


SGP ARM Δt= 5 r= 5
Micropulse Lidar Cloud Cover %
Satellite Mask Cloud Cover %
69%
MPL Ave
Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

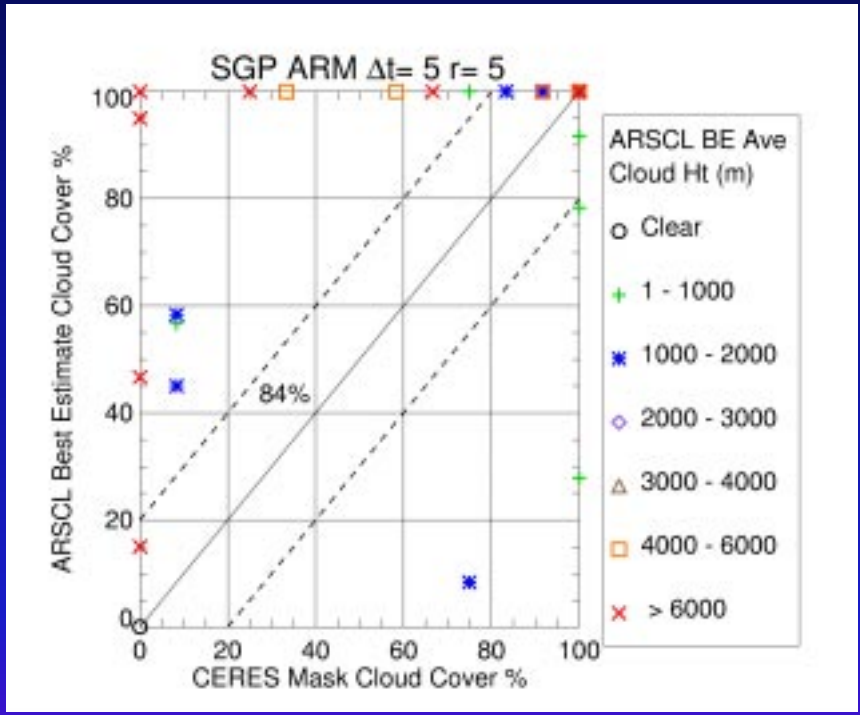
CERES


SGP ARM Δt= 5 r= 5
Micropulse Lidar Cloud Cover %
CERES Mask Cloud Cover %
78%
MPL Ave
Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

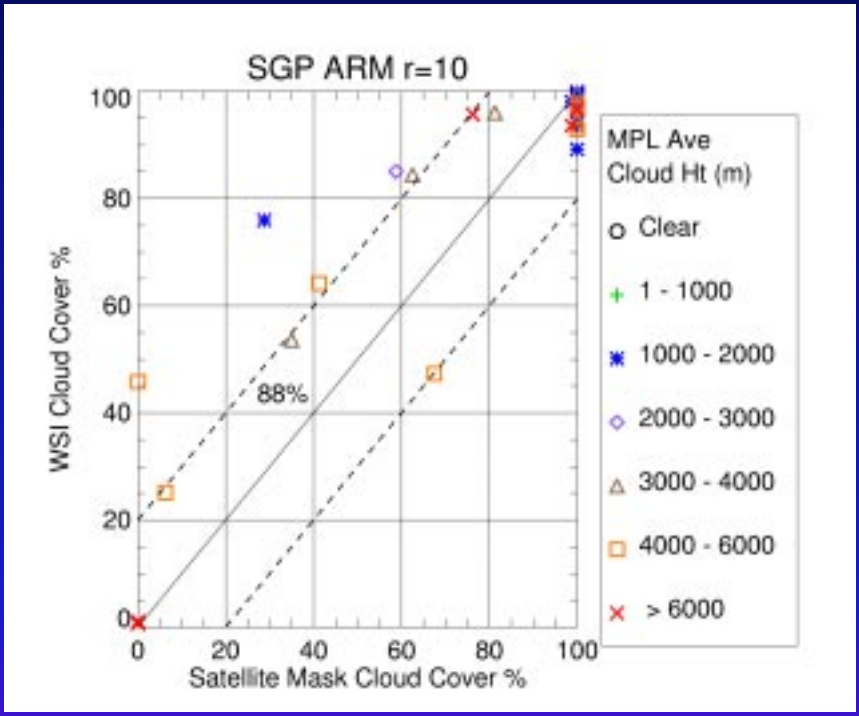
UAH


SGP ARM Δt= 5 r= 5
ARSCL Best Estimate Cloud Cover %
Satellite Mask Cloud Cover %
76%
ARSCL BE Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

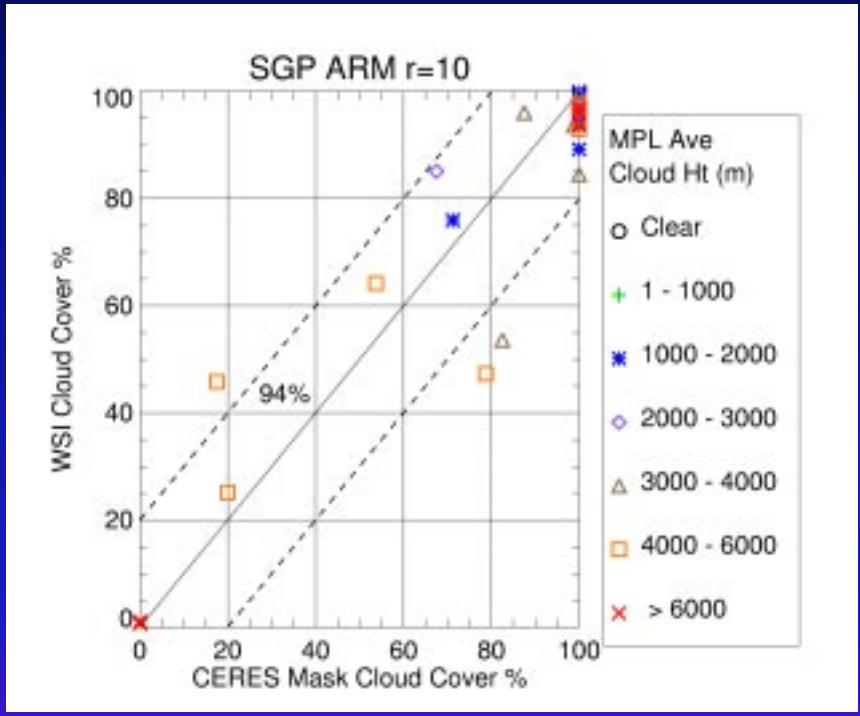
CERES

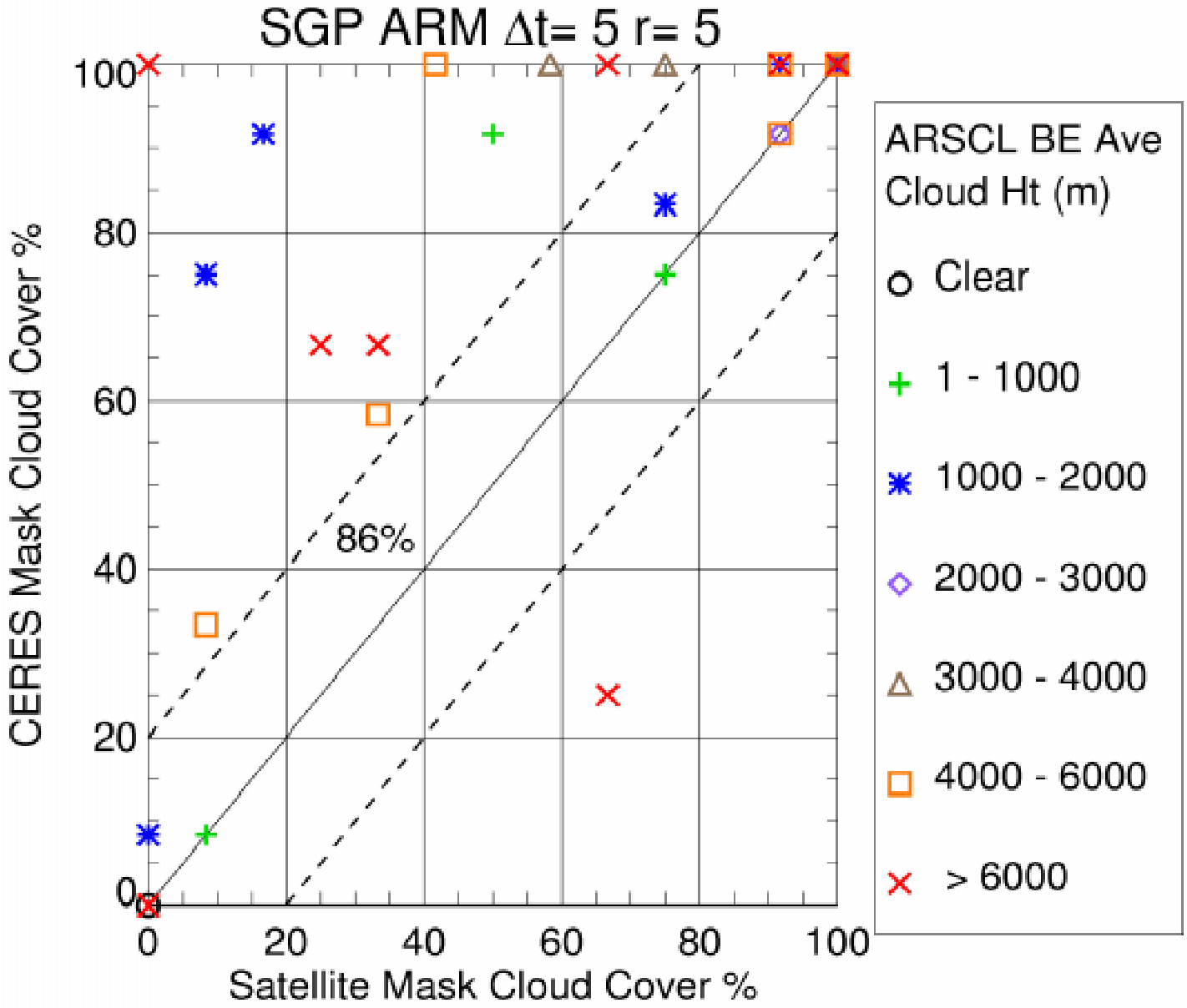

SGP ARM Δt= 5 r= 5
ARSCL Best Estimate Cloud Cover %
CERES Mask Cloud Cover %
84%
ARSCL BE Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

UAH


SGP ARM r=10
WSI Cloud Cover %
Satellite Mask Cloud Cover %
88%
MPL Ave
Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

CERES


SGP ARM r=10
WSI Cloud Cover %
CERES Mask Cloud Cover %
94%
MPL Ave
Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000


SGP ARM Δt= 5 r= 5
CERES Mask Cloud Cover %
Satellite Mask Cloud Cover %
0
20
40
60
80
100
86%
ARSCL BE Ave Cloud Ht (m)
Clear
1 - 1000
1000 - 2000
2000 - 3000
3000 - 4000
4000 - 6000
> 6000

Summary

- Neural network cloud accuracy > 96 %
- NSA cloud cover intercomparison
  - VCEIL, MPL, MMCR agree with mask 72 – 79 %
  - ARSCL composite better, agrees 80 – 82 %
  - WSI best agreement 83 %
- SGP cloud cover intercomparison
  - Lower agreement with satellite, 38 – 76 %
  - MPL worst 38 % - too much cirrus
  - WSI best 76 %
- Cruise ship - preliminary
  - VCEIL 53 %, TSI 68 %

Conclusion

- Some surface Instruments find more cloud
  - MPL and MMCR more sensitive to thin (cirrus)
  - Satellite mask may be missing some cirrus and sub-resolution cumulus
  - Nonhydrometeors detected as cloud?
- Composite ARSCL data improves agreement if component data is good
- WSI and TSI provide best agreement
- Validation requires multiple instruments / data
- CERES agrees well with ground data at SGP
- CERES and our mask agree to 86 % at SGP

Future Work

- Revise classifier to fix problem areas
- Validation paper submitted to JGR
- Refine interpretation of instrument data
- Distribute database and code
- Free IVICS visualization software
  - http://www.nsstc.uah.edu/ivics